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EDITORIAL NOTES.

GEOLOGISTS will note with satisfaction that the University of Cambridge on May 19 conferred the honorary degree of Doctor of Letters on the Abbé Henri Breuil, Professor of the Institute of Human Palæontology at Paris. The following speech was delivered by the Public Orator in presenting the Abbé for his degree: "De gentis humanæ originibus multi antiquitus disputaverunt nec adhuc compositæ sunt controversiæ. Utrum simiis oriundi simus an angelis, ingens fuit rixa. Ossibus nonnullis inventis pithecanthropum quidam finxerunt,

monstrum horrendum, informe, ingens,

cui lumen non datum. Ex contrario hospes noster cavernas speluncasque Gallicas et Hispanas exploravit, proavorum domos nostrorum et picturis plenas invenit, ex quibus patefactum est ante multa annorum millia vel humanissimos fuisse. Ita linea usi sunt et colore, ita vitae studuerunt, ut cervi depicti vel animum cerneres, dum respectat inhians, et crura movet defatigata. Elephanti primigenii dentes et capillos, equi nasum retusum, rhinocerotis lanam, et noverunt et pinxerunt. Abbatem ergo, qui gentem nostram in humanitatem vindicaverit, laeti salutamus.

"Duco ad vos virum admodum reverendum HENRICUM EDWARDUM PROSPERUM BREUIL."

We hear that Abbé Breuil has spent several weeks in visiting the more interesting British localities that have furnished information concerning prehistoric man, and we hope that he may publish an account of his observations in our Islands.

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ON February 20, 1920, Mr. R. Bullen Newton retired from the post of Assistant in the Geological Department of the British Museum, after forty years' service. For twelve years, from 1868 to 1880, Mr. Newton was Assistant Naturalist on the Geological Survey, and in the latter year, owing to special qualifications in the curating of fossils, he was transferred to the British Museum as an Assistant in the Geological Department, then under the keepership of Dr. Henry Woodward. He has therefore completed a period of fifty-two years spent in palæontological work. Owing to pressure

on our space it is not possible at the moment to give an adequate account of his distinguished career, but we intend to do so at an early date. It must suffice here to say that he has accomplished an enormous amount of sterling work, a full bibliography of his publications, including joint work, running to no less than ninety-five items, and covering investigations in the palæontology of almost all regions of the world where fossils are found. Mr. Bullen Newton has also occupied the positions of President of the Malacological Society of London (1910–12), and of the Conchological Society of Great Britain and Ireland (1913–15), and his special interests have always lain in the direction of the Tertiary and younger formations.

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We have received a copy of the Third Annual Report of the Conjoint Board of Scientific Societies, covering its activities for the year 1919. Several of the Committees deal with matters possessing geological interest, such as those on Iron-ores and the Water Power of the Empire. A Committee formed jointly by this Board and the British Association has entered into negotiations with the University of Cambridge and the Imperial College as to the possibility of obtaining funds for the establishment of a Geophysical Institute. The most interesting report, however, is that of the Petrophysical Institute Committee, of which Sir Jethro Teall is chairman and Professor Fearnsides secretary. A full report has been drawn up on the need for a national institute to investigate the conditions of crystallization of minerals and rocks, and advice has been obtained from the Geophysical Institute and the Carnegie Institution at Washington. The Committee is now prepared to approach the Department of Scientific and Industrial Research with a view to the organization of a Petrophysical Institute.

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The twelfth annual report of the governing body of the Imperial College of Science and Technology contains much matter of interest, especially a full account of the work of the Department of Geology, including Mining Geology and Oil Technology, and of the Department of Mining. As is the case everywhere at present there was much overcrowding, and some intending students in Mining Geology had to be excluded owing to lack of equipment. It is impossible in the space at our disposal to mention even a small part of the important work of teaching and research which is being carried on at this great college; its activities cover almost every possible field of learning and technology to which geology can be applied, and we can only congratulate Professor Watts, Professor Cullis, and their staff on the brilliant results attained. It is pleasing to observe that a large proportion of the original papers published during the year by members of the various branches of the Department of Geology appeared in the pages of the Geological Magazine.

The Report of the Non-Ferrous Mining Committee

DURING the last few months we have frequently referred in our Editorial Notes to the proceedings of the Board of Trade Committee on the Non-ferrous Mining Industry. This committee—which was composed as follows: Mr. H. B. Betterton, M.P. (chairman), Mr. H. F. Collins, Mr. J. Harris, Dr. F. H. Hatch, Mr. R. A. Thomas, Mr. J. Wignall, M.P., and Sir Lionel Phillips, who was obliged to resign very soon after appointment—has now with commendable promptitude issued its report, a document of much interest from many points of view. While not primarily concerned with the geological aspects of British non-ferrous mining, the Committee have nevertheless investigated with some thoroughness certain geological matters in connexion with the tin lodes of Cornwall, the lead-zinc deposits of northern England, Scotland, and Wales, and the barytes of Shropshire. A most interesting extract is given from a report by Dr. Malcolm Maclaren to Messrs. Bewick, Moreing and Co., on the central mines of the Camborne-Redruth area, summarizing his views on the limits in depth of profitable tin working in that district. Dr. Maclaren points out that in most instances there is a marked falling off in tin-content at an average depth below the granite-killas contact of about 200 fathoms, or some 360 fathoms from the surface; only in one case, the well-known Dolcoath ore-body, did productive ore extend much below this; even this has failed at about the 500 fathom level. The facts here summarized are entirely consistent with the views as to the existence of definite mineral zones brought forward in the recent paper by Dr. W. R. Jones at the Institution of Mining and Metallurgy, and in the discussion on that paper by Professor Cullis, Mr. Rastall, Dr. Hatch, and other speakers. Favourable reference is also made to the projects for exploration below the abandoned shallow mines of this district by means of cross-cuts driven from the workings of the larger and deeper mines. It is certain that the granite-killas contact must extend far to the north of its surface outcrop at no very great depth; there is every probability that this contact is in point of fact an undulating one, and account must be taken of the fact that granite again comes to the surface at St. Agnes, where also there is well-developed mineralization. It seems probable that all the granite bosses of Cornwall and Devon are in point of fact local domes, cupolas in the American sense of the term, on the surface of a great bathylith, underlying the whole region at a rather small depth. It is of course uncertain what this actual depth may be, and in places it is probably below the limit of working under present conditions; there is also the further fact to be taken into account that in America it is believed that ore-minerals tend to concentrate themselves in the upper parts of these cupolas. Hence it is not safe to infer the existence of a tin-zone all over the upper surface of the

bathylith. Nevertheless the widespread occurrence in the shallower mines of copper lodes is an encouraging feature from this point of view, suggesting the existence below them of the tin, wolfram, and arsenic zones. Several witnesses before the Committee asked for financial assistance from the Government to assist explorations of hitherto undeveloped deep-level areas, and it may be said that geological theory, so far as it goes, is favourable to the prospects of a successful issue.

Considerable space is devoted to a description of the projects for the drainage to lower levels of the Halkyn–Llanarmon area in Flintshire, which is considered to be perhaps the most important area of lead and zinc ores in the whole country. Here the problem is mainly geological, and depends wholly on the well-known water-carrying capacity of the Carboniferous Limestone and the consequent peculiar behaviour of the river system of that district. Here the geology is perfectly simple, and the whole question is now mainly financial; if the project for the continuance of a new sea-level drainage tunnel (which has been already started) can be carried out, some extraordinarily rich and productive veins can be worked down to a much lower level than at present, and a large addition made to the home supply of lead and zinc for many years to come. This seems to be pre-eminently a case for Government assistance. The case for a similar scheme for the Wanlockhead and Leadhills district appears to be less convincing, and neither the companies concerned nor the royalty owners seem to display much enthusiasm on the subject, owing to the immense capital expenditure necessary for a 7 mile tunnel in hard Palæozoic rocks.

Another point of geological interest arises in connexion with the lead-zinc deposits of Northumberland, Durham, and adjoining counties, which are chiefly in the Great Limestone, and are approaching exhaustion. Professor Louis suggested in evidence before the Committee that trial should be made of the Melmerby Scar Limestone as another possible productive horizon. This raises an interesting question as to the influence of the Whin Sill on ore-deposition in this neighbourhood, as to which little information seems to be available. It is generally stated that in Derbyshire lead-zinc ore-bodies are not found in payable quantities below the toadstone, a presumably impervious igneous rock; this suggests a downward movement of the mineralizing solutions. On the other hand, according to accepted modern theories of ore-deposition, the movement should be upward and the ores found *below* the igneous rock. To one unacquainted with local conditions the question at once suggests itself whether proper explorations have ever been carried out below the toadstone, or whether the absence of ore there is an assumption. With regard to the Whin Sill and the northern area the same question is pertinent; as is well known, the Whin Sill is transgressive, occurring at different horizons in the Carboniferous at different places, and it may be suggested that

explorations should be carried out specially in localities where the sill is either immediately above or immediately below an important limestone, with a view to testing the validity of the two lines of contradictory argument as above set forth.

With regard to practical and administrative matters the Committee have dealt with many points, such as mineral leases, wayleaves, easements, the incidence of taxation, royalties, wages, State aid, and mine regulations in general. This is not the place to discuss any of these in detail, but it is permissible to say a few words as to what is in some ways the most important recommendation of the Committee, namely the constitution on a permanent footing of a Mines Department; it is suggested that the existing Mineral Resources Development Branch of the Board of Trade should be expanded and furnished with a suitable technical staff, including mining engineers and mining geologists, with a view to its ultimately forming a sub-department for metalliferous mining of a new Mines Department under the control of a minister. This is a most important recommendation, and it is highly desirable that it should be carried out at once. We have already more than once drawn attention to the existing overlapping of duties, waste of time and expense that will arise from the present multiplicity of authorities controlling the mining industry of the British Isles, and we look forward with confidence to the time when all of these will be centralized and co-ordinated into one organization adapted to the needs and potentialities of this great industry.

ORIGINAL ARTICLES.

A Recent Worldwide Sinking of Ocean-level

By REGINALD A. DALY, Harvard University, Cambridge, Massachusetts.

Introduction.
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Gulf of St. Lawrence.
Maine.
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Difficulties of an Inductive Study of Records.
British Isles.
Atlantic Coastal Plain of the United States.
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Amount of the Eustatic Change.
Contemporaneity and Age of the Strands.
Cause of the Eustatic Change.
Conclusion.

LOCAL uplift and local sinking of the earth's surface have been fully demonstrated for past geological epochs. The amounts of these movements have generally been stated with reference to the present sea-level, and for the greater movements the statements of magnitudes are not seriously impaired by the fact that general sea-level itself has been shifting, upwards and downwards, through geological time. Among the causes for general or "eustatic" shifts of sea-level are: appropriate crustal movements whereby the volume of the ocean basin has been changed; delta-building and volcanic eruption on the sea-floor, the displacement of sea-water not being compensated by crustal sinking; volcanic addition of new water to the ocean; subtraction of water which becomes chemically bound during the alteration of rocks; glaciation on land, lowering sea-level by the abstraction of water from the ocean; deglaciation on land, raising sea-level; changes in the earth's centre of gravity and in her speed of rotation.[1]

Numerous as these possibilities are the proof of a eustatic change in shore-levels is not easy. In the following pages are recorded some field facts which suggest the probability of a sinking of general sea-level to the extent of about 20 feet during the human period. The

[1] The writer has recently found that A. Tylor (GEOL. MAG., 1868, p. 576, and 1872, p. 392) anticipated even Belt in relating the origin of coral reefs to the shift of ocean-level consequent on deglaciation. W. B. Wright (*The Quaternary Ice Age*, London, 1914, p. 417) believes the submerged forests of the British Isles prove a eustatic shift of 55 to 60 feet, if not of considerably greater amount, and attributes it to deglaciation.

suggestion is published, not to express a fixed conclusion, but to invite criticism by those familiar with shorelines in different parts of the world, for the testing of the idea is manifestly a worldwide problem.

The matter is important because it affects judgment as to the reality of many so-called uplifts of land or sea-bottom, and because a close study of the latest shift of sea-level may help to systematize the criteria for earlier and larger eustatic shifts.

Field Observations.

First Contact with the Problem.—The hypothesis of a Recent, negative shift of sea-level first suggested itself to the writer nearly twenty years ago, while engaged in the correlation of post-Glacial elevated strands in Labrador and Newfoundland with those of Quebec. The highest strand mapped between Newfoundland and Nachvak Bay, 500 miles to the north-west, was found to be strongly warped; its gradient varies from 1 to 3 feet per mile, measured along the coast and thus not at right angles to the isobases. The highest strand in Maine has maximum gradients of 5 or more feet per mile. Ice attraction fails to account for such high values and even for the lower gradients of the old strands around the Great Lakes, where also crustal warping is generally credited. On the other hand, the lowest emerged terrace along the shores of the Gulf of St. Lawrence was seen to be conspicuously level throughout a distance of 300 miles or more below Quebec City. The apparent uniformity of level prompted the question whether this particular strand had been abandoned by the waves because of a sinking of general sea-level. For lack of accurate levelling, definite correlation with the more closely studied, lowest beaches of Labrador was impossible, and with the data in hand serious belief in the hypothesis of a eustatic change was withheld.

However, that explanation was recalled by the discovery of new facts during recent field studies on the shores of New England, Florida, and the Samoan Islands. Meantime, Goldthwait had made a careful study of the St. Lawrence strand, to which he gave the name "Micmac terrace"; the results of his levelling agree so well with those made in the other regions mentioned that the suspicion of past years has become a hypothesis that seems to deserve more attentive consideration.

For the opportunity to collect data from the two tropical regions the writer is indebted to Dr. A. G. Mayor, Director of the Marine Laboratory of the Carnegie Institution of Washington.

Gulf of St. Lawrence.—In his excellent account of the Micmac terrace, Goldthwait writes: "Traces of wave work along the south coast of the Saint Lawrence were found at all altitudes below the upper limit of submergence. Contrary to expectation, again, there proved to be no shoreline below the highest one, with the exception of the twenty-foot [Micmac] strand, which possesses enough

individuality of character, enough strength of expression, or enough continuity to indicate a long stand of the sea at any level. Distinct beach fragments were found at all altitudes, in such places as were peculiarly favorable to exposure to the open sea, or in supply of beach material. This is believed to indicate that the emergence of the Saint Lawrence valley from the Champlain sea was not accomplished by spasmodic uplifts, separated by intervals of repose, but was fairly steady and continuous. . . . In marked contrast with the weak beaches at higher levels, the shoreline which stands 20 feet above the sea is strong and continuous."[1] Similarly, the present writer could find no sure evidence of pronounced halts in the uplift of Labrador, where, however, the great strength of the bed-rocks and the general absence of thick glacial drift would in any case forbid the development of continuous beaches or benches in the time available. For the same reasons the topographic equivalent of the Micmac terrace would not be expected in Labrador, except quite locally, even if the emergence took place at identical rates in the two regions. The width of the Micmac terrace varies from a few feet to 1·5 miles or more. Though only a part of its width is due to wave-cutting, and though the formations affected are relatively weak, the 20 ft. higher level of the sea must have been steadily kept for a large fraction of post-Glacial time.

Farther east in the Gulf of St. Lawrence, at Anticosti, Twenhofel found elevated shorelines at intervals up to 350 feet above sea. "The lowest is between eight and fifteen feet above high tide." The corresponding terrace "reaches a maximum width of more than two miles and will average more than one-fourth mile". On the eastern two-thirds of the south coast for about 80 miles, this terrace is two or more miles wide, and is described as occurring in many other parts of the island.[2]

At Arisaig, Nova Scotia, on Northumberland Strait, Twenhofel noted a "raised" beach, roughly estimated to be 25 feet above sea (mean water-level ?).[3]

Maine.—"Throughout the region of Penobscot Bay the best defined and most widely developed terrace has an elevation of 20 to 25 feet above sea-level."[4] In the Rockland folio of the United States Geological Survey Bastin writes (1908): "The most widely developed terrace stands about 15 to 25 feet above mean tide." Along the Maine coast in general Stone noted evidence of a pause in the post-Glacial "fall of the sea" at an elevation of 20 feet above (mean ?) sea-level.[5] The present writer's field observations accord with these published statements, which indicate a recent,

[1] J. W. Goldthwait, Amer. Journ. Sci., vol. xxxii, 1911, pp. 293–4.
[2] W. H. Twenhofel, Amer. Journ. Sci., vol. xxx, 1910, pp. 66, 69.
[3] Ibid., vol. xxviii, 1909, p. 147.
[4] G. O. Smith, E. S. Bastin, and C. W. Brown, Penobscot Bay folio, U.S. Geol. Survey, 1907, p. 13.
[5] G. H. Stone, Monograph 34, U.S. Geol. Surv., 1899, p. 53.

lengthened stand of the sea along the Maine coast at a level nearly 20 feet higher than the existing high-tide level.

The similarity of levels for the lowest terraces in areas so widely separated as the Maine coast and the Gulf of St. Lawrence, and the failure of the 300-mile Micmac terrace to show a distinct tilt, although it runs athwart the isobases of post-Glacial uplift, are both difficult of explanation by assuming crustal uplifts. Confidence in the alternative hypothesis of a eustatic shift was greatly increased by 1919 studies of shorelines in Samoa, about 7,000 miles from the St. Lawrence.

Samoa.—Mayor had already found wave-cut rock-benches, about 8 feet above high tide on all sides of Tutuila, the largest island of American Samoa.[1] The island is 16 miles long. At its eastern end is Aunuu Island, and about 60 miles farther east is Tau Island of the Manua sub-group. The writer found very fine wave-cut benches at 8 to 10 feet above high tide on Aunuu and Tau, and others at the same general elevation on Olosega Island, 7 miles west of Tau. The distance between the most widely separated benches is 75 miles; nowhere in that long line did the bench crests depart essentially from a constant level. Explanation by local uplift was at once seen to be highly improbable, for crustal uplift of such uniformity is unknown to geology.

Eight or ten feet of bench elevation does not, however, measure the total of recent emergence in Samoa. At several points in Tutuila large sea-caves were found. Their floors varied in height above high tide, from 14 or 15 feet at their mouths to 25 feet at the back walls of the caves. Many caves of similar forms and cut in similar rocks are being made by the surf of the present day. The lower lips of the newer caves are characteristically 4 to 6 or more feet below high-tide level, and the floors rise inwards to heights of a few feet above high tide. Hence the emerged caves were cut when the sea-level was nearly 20 feet higher than now. That assumption also explains the 8 ft. benches, for the cliffs now being cut on the Samoan headlands (where not protected by coral reefs) have regularly about 12 feet of water directly at their feet during high tide. The writer fully agrees with Mayor's conclusion that reef corals were not living on any of these Samoan shores when the emerged caves and benches were developed.[2] Hence the reefless, or nearly reefless, headlands of the present time are those where the relation between sea-level and bench-level of the earlier period is best determined. It may be added that no evidence of a negative shift of sea-level greater than about 20 feet could be found in the Samoan Islands. If they ever were submerged more deeply, the evidences have been removed by erosion.

The equivalence of the negative shift of sea-level in Samoa and along the east coast of North America is shown not only by its

[1] A. G. Mayor, Proc. Nat. Acad. Sci. vol. iii, 1917, p. 523.
[2] Ibid., p. 522.

amount, but also by the state of preservation of the strand marks. Allowing for lithological differences, cliffs, benches, caves, and chasms have comparable strength of development in the two regions, in each of which the sea must have worked a relatively long time at the 20 ft. level. Since the shift of level the surf has destroyed a part of each bench in Samoa, therewith doing work roughly equal to the destructive wave-work already performed on equally hard rocks in Maine.

Difficulties of an Inductive Study of Records.—The hypothesis of a eustatic change must meet the obvious test of matching the facts observable on the shores of every continent and nearly all islands. That the application of the test is not easy will be clear from the following considerations.

1. Most shores have not been studied with requisite thoroughness. The compilation of the published, appropriate records, incomplete as they are, is a herculean job. Apart from the time and physical labour involved, the compiler is baffled by the psychology of many authors, who have observed in the field and then written their records under the more or less unconscious control of the uplift hypothesis. Relevant and perfectly accessible facts have therefore not been noted. Moreover, the selection of data in statistical study has its own obvious danger for the compiler.

2. Writers have not always been careful to give the datum from which the level of each "raised" strand was measured. In general "sea-level" is mentioned without specifying mean level or high-tide level or any other unequivocal datum. The omission is serious for the compiler dealing with a shift of only 20 feet.

3. The marks of a higher stand of sea-level depend for their clearness on several highly variable factors, including: the strength and other characters of the shore rocks; the exposure of the coast as it affects the fetch and power of the waves; the power of tidal currents; the position of wave-base at the old shore, especially the depth of the rock-bench cut by the waves at the foot of a receding sea-cliff; the degree to which the records of the higher stand of the sea have been destroyed by the waves acting at present sea-level.

The influence of rock variation is well illustrated in New England, where glacial deposits were distinctly cliffed at the 20 ft. level, while the massive granites suffered little benching. As already stated, the contrast between the shores of the St. Lawrence and those of Labrador in this respect is very striking. Even where the shore materials were quite incoherent, as along young coastal plains, sea-cliffing might not have taken place systematically at all. Modern examples show prograding, rather than retrogression, of the shore-line. Thus the sea-cliffs of the 20 ft. strand would vary in height from zero upwards.

The crest of a storm beach is not sea-level. The more powerful the waves the greater is the difference of these two levels. From published texts one can not always be sure that due allowance

has been made for the difference in estimating former sea-level from emerged beaches.

Variation in the position of wave-base is worthy of special attention. Waves running in on a flat shallow shelf are damped, so that wave-base approaches a minimum depth inshore. Wave-base is deeper along a steep-to shore, other things being equal. In the former case the foot of the sea-cliff is characteristically at or near high-tide level; in the latter case it is typically well below high-tide level, as exemplified in Samoa, where many headland cliffs plunge into water about 2 fathoms deep. Generally old strand-levels on oceanic islands are likely to be notably higher than the corresponding wave-cut benches, as well as 2 to 10 or more feet lower than the level crests of storm beaches.

4. Wherever a coastal region is now undergoing, or has recently undergone, a crustal movement, the search for local evidences of an earlier eustatic sinking of ocean level may give negative or doubtful results. The marks of the old strand may be drowned, or else elevated to heights which are not to be directly correlated with the heights of the old strand in undisturbed rocks.

5. In special cases the eustatic shift may locally cause a change in the tidal range, affecting the datum if this be high tide.

6. Finally the height of the old strand line above mean sea-level may depend on the cause of the eustatic shift. Suppose, for example, that a shift of level averaging 20 feet were due to a recent increase of the ice-cap on the Antarctic continent. Near the ice-cap sea-level would be kept, through gravitative attraction by the new ice, a little higher than it would be if abstraction of water from the ocean were the only cause for the change of level. In the northern hemisphere the lowering of sea-level would be all the greater because of attraction to the new ice.

For many reasons, therefore, the search for complete proof of the eustatic shift here postulated is bound to be prolonged. Meantime a preliminary study of some records made in separate mutually distant regions has been made, with results that also show the hypothesis to merit discussion and further testing. Certain examples may now be briefly reviewed.

British Isles.—The raised beaches of Scotland and Ireland are celebrated, and like the American cases already noted, occur in an area of uplift following deglaciation. In Scotland the uplift was differential, but according to most published statements the lowest beach is at nearly constant level, which is sometimes described as about 20 feet or about 25 feet above Ordnance datum. Ordnance datum is mean water-level at Liverpool, so that the beach varies from 15 to 20 feet above local high tide, according to these statements. Geikie writes: "The most prominent of all the raised beaches is that which lies at a height of about 20 or 25 feet above high water . . . varying in breadth from 6 or 7 miles to not more than a few feet." Along its inner edge are sea-cliffs, caves, sea-stacks,

and skerries. "This beach must be more or less familiar to every one who has visited almost any part of the coast-line of Scotland."[1]

Many memoirs of the Geological Survey of Scotland bear references to this beach, which is described as seen "at frequent intervals", or as "conspicuous" or as the "best developed". In the Clyde area, the Loch Fyne area, Skye, and elsewhere, its fossil shells are those of species now living in Scottish waters. Clough writes: "With regard to the age of the 25-foot beach, the consensus of opinion seems to be that the elevation of the beach was completed in Neolithic times."[2]

In Jamieson's early account of the strand he states that a rise of 25 or 30 feet (above Ordnance datum ?) is indicated, and that it "seems to have been very general along the shores of this country". He concluded that the uplift was unequal; "consequently it is the land that has risen, and not the sea that has sunk."[3] Fifty years later Wright published a sketch-map of the "25-foot beach", showing a maximum height (above Ordnance datum ?) of over 35 feet near Loch Linnhe, in Western Scotland, from which point the elevation declines—to reach zero on the south-east and north-west shores of Ireland, in northern Wales, and in the North Sea.[4] Wright's placing of this strand-line does not altogether agree with the descriptions published by A. Geikie, Kinahan, Hull, and others, but would indicate late Neolithic warping.

According to Kinahan, "the 25-feet sea beach all around Ireland rises and falls very similarly to the levels of the present sea-margin," though he adheres to the uplift hypothesis as the only one to be considered in explanation. The old level is marked by cliffs, stacks, sea-caves, and beaches; on open seaboards they have been largely destroyed by waves breaking at present sea-level. From Wicklow, southward, the strand is at about the 22 ft. contour. North of Dublin Bay it is below the 20 ft. contour. In the old estuaries it has been placed nearly on the 25 ft. contour, perhaps illustrating the influence of the tides in causing different initial levels. Human relics and shells of species now living in the Atlantic have been found in the Irish beaches also.

Hull described the "25-feet terrace" as the most striking and continuous of all the "raised" beaches of Ireland, and correlates it with the 25 ft. strand in Scotland. However, he gives the average elevation of the Irish beaches as 15 feet.[5] The contrast in elevations

[1] A. Geikie, *The Scenery of Scotland*, 2nd ed., London 1887, pp. 381–2.

[2] C. T. Clough *The Geology of the Glasgow District* (Mem. Geol. Surv. Scotland), 1911, p. 192.

[3] T. F. Jamieson, Quart. Journ. Geol. Soc., vol. xxi, 1865, pp. 188–90.

[4] W. B. Wright, *The Quaternary Ice Age*, London, 1914, p. 422. According to a personal communication from Mr. Wright (November, 1919) the zero isobase should be drawn considerably farther south in Ireland and Wales.

[5] G. H. Kinahan, *Manual of the Geology of Ireland*, London, 1878, pp. 251–8; E. Hull, *The Physical Geology and Geography of Ireland*, 2nd ed., London, 1891, p. 137.

may be connected with the difference of datum-levels assumed in the two countries. Ordnance datum in Ireland is 8 feet below Ordnance datum for Great Britain (mean water-level at Liverpool, which is practically the same as in Ireland). In general, 25 feet above Ordnance datum in Scotland means 20 feet or less above high tide, the significant level.

For a total distance of about 1,000 miles along the southern shores of England, Wales, and Ireland, a "pre-glacial" terrace "has been traced almost continuously". It occurs also in France, from Calais to beyond Brittany. "Throughout the greater part of this district it stands uniformly some 10 or 12 feet above the present high-water mark, and maintains a remarkable parallelism with the present sea-level. This parallelism proves almost beyond a doubt that no permanent deformation by folding or faulting has taken place over this wide area since pre-glacial times."[1] The "pre-glacial" age is deduced from the presence of boulder-clay and early "Pleistocene" fossils on the rock-bench cut when the sea stood at the higher level. Wright holds that the old strand owes its position to a eustatic oscillation of sea-level.

The progress of discoveries and ideas concerning the lowest strands in the British Isles shows one kind of danger into which a compiler may run if the record of relevant facts is inadequate. Considering the many statements by good observers as to the continuity of the 20 ft. level or of the 25 ft. level all around both Great Britain and Ireland, it would look as if these islands could afford excellent corroboration of the eustatic hypothesis. When, however, strand-lines of about the right elevation are found to be partly "pre-Glacial" and partly post-Glacial, and when it is further suggested that the later beach-level has been deformed, the difficulty of using the British data is clear. If Wright's view as to the warping of the Neolithic beach (the 25 ft. or 20 ft. beach of Scotland and Ireland) is correct, then the relation of this very extensive strand-line to the eustatic hypothesis could only be established after the dates of the warping and the eustatic shift become known. Meantime the British Isles represent a region where the ascertained facts, in spite of their complexity, point to these islands as a field where special tests of the eustatic hypothesis should be made.

Atlantic Coastal Plain of the United States.—Other questions arise in connexion with the lower parts of Atlantic coastal plains recently emerged. For example, the Cape May formation of New Jersey and Pennsylvania and the correlated Talbot formation of Maryland emerged from the sea not many thousand years ago. Their surfaces lie in general below the 20 ft. contour, but strata with surfaces at 40 or 45 feet have been included in each formation. In the north

[1] W. B. Wright, *The Quaternary Ice Age*, London, 1914, p. 423; *The Geology of the British Isles*, edited by J. W. Evans (*Handbuch der regionalen Geologie*, iii 1), The Hague, 1918, p. 299. Cf. J. Prestwich, Quart. Journ. Geol. Soc., vol. xlviii, 1892, p. 263.

the "lower Cape May terrace" does not rise beyond the 20 ft. contour. Is there evidence of such a halt in the emergence of the Talbot formation?[1]

Similarly, the lower division of the Pensacola terrace in Florida, like the Satilla terrace in Georgia, seems to correlate with the Recent 20 ft. eustatic shift. The Pensacola terrace "is a broad plain, rising less than 40 feet above sea level, and apparently including two divisions, one being less than 20 feet above, and the other from 20 to 40 feet above sea level."[2] The greater part of the Satilla terrace, which merges into the Pensacola terrace, "is 15 to 25 feet above sea level, but there are a few places which reach an elevation of about 40 feet. . . . If the coast region were uplifted 15 or 20 feet above its present elevation, a plain now submerged beneath the ocean waters would appear as an emerged terrace lying east of and parallel to the Satilla terrace, and separated from it by an escarpment. This plain would be analogous to the Satilla plain in all its essential features."[3] Since the Pensacola-Satilla terrace keeps a practically uniform set of levels for an air-line distance of 500 miles, the hypothesis of its emergence by crustal uplift seems hardly credible.

Florida Keys and West Indies.—Vaughan has deduced a recent sinking of sea-level of from 10 to 15 feet along the coral-reef keys of Florida, and "perhaps 10 to 20 feet" along the keys west of Bahia Honda.[4] He described New Providence Island of the Bahama group as "mostly a platform from sea-level to 20 feet in elevation", and the neighbouring Andros Island as having the same range of emergence. On New Providence Island he discovered a wave-cut scarp at 10 feet above "water-level", and other benches at only 3 or 4 feet above the sea, but he also found a sea-cave at Nicollstown Light, which indicates an emergence of about 18 feet.[2] This case of apparent conflict in the testimony of bench and sea-cave as to the amount of level-shifting is strikingly like that at Tutuila, Samoa, already described.

In Cuba the Seboruco "reef" represents a recent "uniform" emergence; it "borders the coast in most places" and constitutes many islets surrounding the main island. "Generally these are low, standing only a few feet above the water." In Jamaica Hill found "elevated reefs" at 25 feet and 10 feet above "sea-level",

[1] Cf. M. Fuller, Prof. Paper No. 82, U.S. Geol. Surv., 1914, p. 222.

[2] G. C. Matson and S. Sanford, Water-supply Paper No. 319, U.S. Geol. Surv., 1913, p. 34.

[3] O. Veatch and L. W. Stephenson, Bull. 26, Geol. Surv. of Georgia, 1911, pp. 36, 437.

[4] T. W. Vaughan, "A Contribution to the Geological History of the Floridian Plateau": Papers of the Marine Laboratory, Carnegie Institution of Washington, 1910, p. 180. "Preliminary Remarks on the Geology of the Bahamas": ibid. 1914 p. 50. Yearbook No. 13, Carnegie Institution of Washington, 1914, p. 230.

and states that they are persistent on the north, east, and south-west shores.[1]

South America.—According to Branner, the Brazilian coast shows features indicating recent emergence, the amount of which is variously described as "a few meters" to 8 meters.[2] Halle found a "very distinct terrace at 6 meters above sea-level on Gable Island", Patagonia, and another at 6 meters at the mouth of the Rio Grande River, 48 kilometres from Gable Island. The sands of the former terrace bear fossils showing that the contemporary sea had a temperature higher than that now reigning offshore. Halle adds: "These low terraces do not afford any unquestionable evidence of an unequal upheaval."[3] Andersson describes a sea-cut terrace at 3·5 meters on Beagle Channel, Tierra del Fuego, and says that it is the "same beach" as those on Gable Island and Navarin Island. He quotes Nordenskjöld's discovery of a very marked terrace at "about 10 meters above sea-level" on Usuaia Peninsula, Straits of Magellan.[4]

Graham Land, Antarctica.—Andersson also discovered a terrace at 7 meters "above sea-level" on Graham Land, Antarctica, indicating "upheaval" which "does not exceed a few meters".[5]

New Zealand.—Considerable attention has been given by the Government Geological Survey to proofs of recent emergence in New Zealand, with results which may be tabulated as follows:[6]—

District.	*Elevation of "raised beaches" or benches.*
Thames subdivision	Maximum "over 25 feet" (datum ?).
Miranda, across Firth of Thames	10 to 12 feet above high-water mark.
Waihi-Tairua subdivision	Benches "several feet above high-water mark".
Aroha subdivision	Correlated with the last.
Oamaru subdivision	12 ft. bench; accompanying beach with Recent fossils; Papakaio coastal plain at "15 to 25 feet above sea-level".

Australia.—According to Andrews, the numerous coastal plains, emerged beaches, and rock-benches of New South Wales "suggest an apparent elevation of the shoreline to the extent of a few feet in very recent time". The heights of the beaches vary from 1 to 15 feet above high-water mark. "Similar indications of the apparent elevation of the shoreline for a few feet are to be found along the whole eastern side of Australia." The cause is attributed to "either an apparent rise of the land, or a retreat of the sea, to the extent of a few feet".[6] Süssmilch believes that the New South Wales

[1] R. T. Hill, Amer. Journ. Science, vol. xlviii, 1894, p. 203; Bull. 34, Museum Compar. Zoology, Cambridge, Mass., 1899, p. 99. Systematic discussion of the Atlantic Islands would include Bermuda, where R. S. Tarr (Amer. Geol. Vol. xix, 1897, p. 293) found a recent terrace reaching 15 or more feet above sea.

[2] J. C. Branner, Bull. 44, Museum Compar. Zoology, Cambridge, Mass., 1904, p. 170 *et ante*.

[3] T. G. Halle, Bull. Geol. Inst. Univ. Upsala, vol. ix, 1910, pp. 99, 117.

[4] J. G. Andersson, Bull. Geol. Inst. Univ. Upsala, vol. viii, 1908, p. 182.

[5] Ibid., p. 57.

[6] Bulletin No. 10, 1910, p. 29; No. 15, 1912, p. 50; No. 16, 1913, p. 77; No. 20, 1918, pp. 112–13 and p. 4.

coast belt shows recent "uplift" to the extent of "about 10 to 20 feet." An estuarine deposit at Largs, with surface at 15 feet above high-water mark, has yielded more than 30 species of shells of animals now living in the adjacent water. Similar discoveries on the coast of Queensland are reported by Jack and Etheridge, the emerged beaches and plains (locally with recent fossils) having heights of from 10 feet to 20 feet above "sea-level".[1]

Cadell notes that the "raised beaches" of Western Australia are from 10 to 15 feet above sea-level. One of these is from 12 to 18 miles wide, and extends 25 miles inland. The beaches contain recent marine shells.[2]

Pacific Islands.—Many local, recent, negative shifts of sea-level have been recorded in the Pacific archipelagoes, where synthetic studies are needed in so many lines. A few of the records will suffice to raise the question whether the last shift of level in Samoa affected the whole Pacific basin. After his reconnaissance of the Paumotus, Agassiz wrote: "Nearly all the islands have been elevated a very moderate height and probably to about the same height." He gives the figure for Niau as "no greater than 20 feet" and for Rangiroa as 15 to 16 feet.[3] At Funafuti of the Ellice group, David and Sweet found the recent negative shift of level to be "at least 6 feet and almost certainly 16 feet". In another passage they write: "There must have been a land-elevation or a sea-sinking of at least 9 to 10 feet."[4] For the New Hebrides Mawson reports sea terraces, benches, and "raised" shore debris or coral in Santo, Efate, Epi, Malekula, Pakea, and Hui Islands, at heights of from 5 to 15 feet.[5] In his Murray Island report Mayor writes: "In common with other islands of the Torres Straits region, whether volcanic, calcareous, or continental in character, the Murray Islands exhibit a recently emerged shore platform about 3 feet above the present high-tide level."[6] On Bird Island of the Hawaiian Chain, Elschner found a "level terrace" a few feet above sea-level.[7]

As shown in Samoa and in the Bahamas, the observed heights of wave-cut benches on oceanic islands are likely to be 6 to 12 or more feet below the high-tide level ruling at the time of their cutting. "Raised" coral, too, is liable to give too small a value for a negative

[1] E. C. Andrews, New South Wales Handbook, Brit. Assoc. Adv. Science, 1914, pp. 525, 532; C. A. Süssmilch, *Introduction to the Geology of New South Wales*, Sydney, 1911, p. 154; R. L. Jack and R. Etheridge, *Geology and Palæontology of Queensland and New Guinea*, London, 1892, pp. 614 ff.

[2] H. M. Cadell, Trans. Edinburgh Geol. Soc., vol. vii, 1897, p. 179.

[3] A. Agassiz, Memoirs, Museum Compar. Zoology, Cambridge, Mass., vol. xxviii, 1903, p. 20.

[4] T. W. E. David and G. Sweet, *The Atoll of Funafuti*, London, 1904, pp. 68, 84, 85.

[5] D. Mawson, Proc. Linn. Soc. New South Wales, 1905, pt. iii, pp. 400 ff.

[6] A. G. Mayor, Papers from the Department of Marine Biology, Carnegie Institution of Washington, vol. ix, 1918, p. 9.

[7] C. Elschner, "The Leeward Islands of the Hawaiian Group": reprint from the *Sunday Advertiser*, Honolulu, 1915, p. 9.

shift. Until the delicate problem of the relation between the emerged forms and the corresponding sea surface has been worked out, both as to general criteria and as to the local application of those principles, the actual amount of delevelling registered in the Pacific Islands cannot be definitely stated.

California.—Japan, Alaska, and California are examples of the lands where local movement of the earth's crust, upwards or downwards, have taken place during the last few decades. Strand-marks of an ocean-level, which some thousands of years ago was higher than now, must there have altitudes different from contemporaneous markings in more stable regions. Identification of the 20 ft. strand is thereby made specially difficult. Yet Lawson's observations on the emerged zone at Carmelo Bay and Monterey, California, are suggestive for future research. He notes that the emerged terrace reaching 25 or 30 feet above sea-level is the "most defined and persistent elevated terrace in this coastal region", and concludes that the sea beat on the higher shore about as long as it has worked at the existing level.[1] Has the emerged terrace a height slightly greater than that of the Micmac and other terraces because California has been specially affected by diastrophism during the recent period?

Amount of the Eustatic Change.

Without further multiplying examples, those so far mentioned may be reviewed conveniently by the use of the following table.[2] Its full meaning cannot be understood without recalling certain principles. In each case where the author of a record uses "sea-level" or "water level" as his only datum, reference to the more significant and less equivocal high-tide level is not directly possible. The fifth column of the table therefore has many blanks. A wave-cut bench is likely to give too low a value for the emergence; a storm-beach, too high a value. Coral reefs give too low a value unless they can be shown to have grown up to the sea surface (mean or high-tide level) before the emergence began. Even in that instance their crests may have been somewhat abraded by storm waves just after the sea-level began to sink, for a dead coral reef is a friable structure. Special note should be taken of W. B. Wright's view that the British 25 ft. beach has been warped.[3]

In spite of all uncertainties, columns 4 and 5 of the table show that the negative eustatic shift of ocean level which suffices to explain the facts, is close to 20 feet. It may have been a little less; it was probably not as much as 25 feet.

[1] A. C. Lawson, Bull. Dep. Geol. Univ. California, vol. i, 1893, p. 53.

[2] In a verbal communication Dr. E. O. Hovey has stated that at many parts of the Greenland coast he observed beaches with crests 15 to 20 feet above mean sea-level.

[3] See reference above, and also Geol. Mag., Vol. viii, 1911, p. 99.

SUMMARY OF DATA REGARDING RECENT EMERGENCE.

Region.	Features.	Heights given (feet).	Datum stated.	Height above high tide (feet).	Remarks.
Gulf of St. Lawrence	Micmac terrace	14–23	High tide.	14–23	Specially developed.
Anticosti	Terrace	8–15	,, ,,	8–15	Ditto.
Arisaig	Beach	25	Sea-level.	—	Roughly estimated.
Maine	Beaches, benches	15–25	Mean tide.	10–20	Specially developed.
Scotland	,, ,,	20–25	Ordnance.	15–20	Ditto.
,, (Wright)	,, ,,	20 (?) – 35 +	Ordnance (?)	(?)	Ditto.
Ireland	,, ,,	15–25	Ordnance.	15–20 (?)	Ditto
,, (Wright)	,, ,,	0–25 (?)	Ordnance (?)	(?)	Ditto.
New Jersey	Lower C. May terrace	20	Sea-level.	—	Uniform levels for long distance
Maryland	Talbot terrace (in part)	20	,,	—	Ditto.
Georgia	Satilla terrace (greater part)	15–25	,,	—	Ditto.
Florida	Lower Pensacola terrace	20	,,	—	Ditto.
	Keys	10–20	High tide (?).	—	Ditto.
Bahamas	Benches, sea-caves	3–20	Water-level.	—	Platforms wide; sea-cave at 18 feet.
Cuba	Reef	"Few feet."	Sea-level.	—	Persistent.
Jamaica	Reefs	10, 25	,,	—	,,
Brazil	Beaches, terraces	20–25	,,	—	
Patagonia	Terraces	12–32	,,	—	Accord at distant points.
Graham-Land	Terrace	23	,,	—	
New Zealand	Beaches, benches, coastal plain	10–25	,,	—	See table above.
East Australia	Ditto	10–20	,,	—	Uniform emergence.
West Australia	Ditto	10–15		—	
Samoa	Benches, sea-caves	8–15 +	High tide.	8–15 +	Uniform emergence.
Paumotus	Emerged limestone	15–20	Sea-level.	—	
Funafuti	Reef coral	6–16 (?)	High tide.	6–16 (?)	
New Hebrides	Terraces, benches	5–15	Sea-level.	—	
Murray Island	Benches	"Few feet"	High tide.	—	
Bird Island	Terrace (level)	,, ,,	Sea-level.	—	
Carmelo Bay	Terrace	25–30	,,	—	Persistent.

Contemporaneity and Age of the Strands.

A second test of the eustatic change is naturally to be found in the expectation that the delevelling should be essentially synchronous in all parts of the ocean. In fact, observers dwell on the recency of the sea-level shifts registered in all of the illustrative cases. Fossils in the St. Lawrence, Scottish, Irish, Cuban, Patagonian, New Zealand, Australian, Funafuti, Murray Island, New Jersey, Maryland, Georgia, and Florida beaches, reefs, or coastal plains belong to species now living in the adjoining seas, or, exceptionally, to species now living in slightly warmer water. Great recency is also shown by the relatively small damage done by erosion to the strand marks, except in the case of those exposed to powerful surf.

The beaches of the higher latitudes are clearly post-Glacial, and also of date later than the post-Glacial uplifts following deglaciation. Brögger puts the completion of the last 4 metre to 8 metre emergence of the Christiania region at about the year 500 B.C. The development of the corresponding sea-cliffs, benches, and other strand marks is referred by him to the late Tapes (Neolithic) period, between 1400 B.C. and 2400 B.C. All Tapes time is taken to lie between 1400 B.C. and 6700 B.C. During the late Tapes period the Christiania climate was about 2° C. warmer than now.[1] Traces of Neolithic man have been found in the 25 ft. beaches of the British Isles. The emergence of this beach in North Ireland seems to have been completed during Neolithic times.[2]

Perhaps fuller direct evidence for contemporaneity among the lowest beaches may be discovered through the use of fossils. It is significant that the fossils in the Patagonian beaches, like those of Norway, betoken water warmer than the adjacent sea.

Simultaneous emergence for the many separate regions is the more credible because of the similarity in the histories of their respective coasts before emergence. Repeatedly one encounters the description of terrace, bench, or beach near the 20 ft. level as the best developed, the most conspicuous, or the most persistent in a region characterized by "raised" strand marks; illustrations are noted in the foregoing table. Thus, the different regions must have had sea-level nearly constant for a considerable time, during which the strand marks were well incised. This widespread accordance itself must deepen suspicion that local diastrophism has not been responsible for the recent emergence of so many continental and island coasts.

In conclusion, the facts in hand appear to permit belief in the possible synchrony of the different strand markings and emergences here considered, but this second test of the general hypothesis also leads more surely to questions than to definite answers.

[1] W. C. Brögger, Norges geol. Unders., No. 31, 1901, p. 713, and No. 41, 1905.

[2] W. B. Wright, *The Quaternary Ice Age*, London, 1914, pp. 384–5.

Cause of the Eustatic Change.

Before the fact is established it would be idle to dwell overmuch on the explanation of a 20 ft. drop in ocean level. If lands in both hemispheres, in high and low latitudes, emerged simultaneously and to a nearly equal amount, the cause of the emergence cannot be found in a change in the earth's centre of gravity nor in a change in the speed of her rotation. There is no evidence compelling belief that the ocean basin has been so enlarged in recent time as to cause a negative 20 ft. shift of sea-level. More hopeful is the hypothesis of an increase in the volume of existing, non-floating glaciers, an increase taking place a few thousand years ago. If the Antarctic ice-cap were then thickened to the average amount of about 700 feet, an average sinking of sea-level to the extent of nearly 20 feet would be inevitable.

In favour of this suggestion would be evidence of a worldwide oscillation of climate, like that which seems to have affected the Christiania region in Recent time. If the whole earth was in the Tapes period a little warmer than now, less water may have then been taken from the ocean to build the ice-caps; sea-level was a little higher than at present. The oscillation as a whole would be but an incident in a series of climatic changes which began with the opening of the Glacial period.

Conclusion.

The facts on which the hypothesis of a general post-Glacial fall of sea-level is based belong to three groups.

Because of the recency of strand lines now about 20 feet above high-tide level, many of these lines should not have undergone important deformation, and if their emergence was due to the eustatic shift their accordance of level should be observable. Notwithstanding the difficulties attending a canvass of the world's coast-lines, a comparison of published observations seems to show that the speculation will bear the test of a fuller induction founded on special field work.

Naturally less troubled by the danger of subjectivity, the conclusions drawn from a study of the Micmac terrace or the lowest coastal-plain terrace to the southward of New York City are now perhaps more compelling. Practical uniformity for the terrace level along 300 miles of coast in the one case and along nearly 1,000 miles of coast in the other is certainly not expected on the uplift hypothesis, which likewise does not easily explain the strikingly accordant levels of Samoan benches at points only 75 miles apart.

A third group of facts, relating to the necessity of synchrony for the different strands abandoned by the sea, is meagre, but so far as it goes this evidence permits the main hypothesis, and its analysis suggests methods for future research.

The combination of all three groups of observations is much

stronger than any one of them. For that reason the eustatic hypothesis has seemed worthy of statement. The search for proof of eustatic shifts during more remote periods might be easier if even a small modern movement of the kind were proved, especially if its cause were also determined.

Note on the Age of the Milburn Group.

By A. D. N. Bain, B.Sc.

ON the western side of Cross Fell lies a group of beds consisting of andesitic lavas and ashes, with intercalated beds of shale. The shales are tranquilly bedded, testifying to their having been deposited in quiet water. It has therefore been inferred that the igneous material is volcanic, and was poured out on a sea-floor. The beds were first described by Harkness,[1] later by Goodchild,[2] who gave the name "Milburn Group", and subsequently by Professors Nicholson and Marr.[3]

The exact age of these beds could only be approximately determined because of the scarcity of determinable fossils obtained from them. Goodchild recorded *Didymograptus murchisoni* (Boeck), and Professors Nicholson and Marr recorded *Diplograptus dentatus* (Brongn.).[3] Professor Marr assigned them to either the Lower Llandeilo or the uppermost part of the Arenig, at the same time expressing a hope "that local observers will pay special attention to the fauna of these beds, as the exact determination of their age is a matter of considerable importance".[4] Later Goodchild grouped them with the Ellergill Beds, a group of earthy slates underlying the Milburn Group and of about the same age, as being equivalent to the lower part of the Volcanic Series of Borrowdale.[5]

It is in Wythwaite Hole that these beds are best exposed and where they have been generally studied. A good exposure occurs in a similar "hole" to the east of Wythwaite Hole proper, where a band of shale is exposed, quite regularly bedded and lying between masses of andesitic lava. It is about 3 feet thick and dips to the south-east. The lavas above show regular parallel banding, dipping at a greater angle in the same direction.

From this band of shale the following graptolites have been collected by the author[6]:—

[1] Quart. Journ. Geol. Soc., vol. xxi, 1865, pp. 235, 340–1. Cf. Harkness, Quart. Journ. Geol. Soc., vol. xix, p. 127.

[2] Proc. Geol. Assoc., vol. ix, No. 7.

[3] "The Cross Fell Inlier": Quart. Journ. Geol. Soc., vol. xlvii, 1891, p. 502.

[4] Geol. Mag., 1894, p. 128.

[5] *The Geology of the Country between Appleby, Ullswater, and Hawes Water.* Mem. Geol. Surv. England and Wales, Sheet 30 (New Series), 102 S.W. (Old Series), pp. 34 and 39.

[6] A *Phyllograptus*, the species of which has not yet been determined, has also been obtained.

Didymograptus bifidus Hall.
Didymograptus stabilis Elles & Wood.
Didymograptus nanus Lapw.

From the Ellergill Beds exposed in the lower part of Eller Gill I have obtained *Glyptograptus dentatus* (Brongn.). Since these fossils are characteristic of the *Didymograptus bifidus* zone, it would seem that the Milburn Group and the associated Ellergill Beds belong to this zone, and that here, too, volcanic activity began in Upper Arenig time.

In conclusion, I desire to express my sincere thanks to Miss Elles for having determined the graptolites and permitting me to see her determinations, and to Professors Sibly and Marr and Dr. Woolacott for advice.

Isostatic Measure of the Rocky Mountains.

By Charles Keyes, Des Moines, Iowa.

AMONG the enisled high plateaux of Eastern Utah the brilliant isostasy theory had its birth. When these arid mountains first became the subject of special description, about 1880, no such thing as a distinctive desert geology was entertained. Possibility of a definite geographic cycle in land sculpture was one of the modern earth conceptions yet undreamed. Competency of the wind as a general erosive agency was not yet established. Operation of epeirogenic movements was little understood. Omission of such basic considerations necessarily led to curious aberration in interpretation of the phenomena presented by lands of little rain.

Following closely the rather unscientific Powellian policy of geological saisissement, Captain Dutton entirely missed the larger physiographic significance of his wide observations on the prodigious erosion which the Utah region had manifestly undergone in relatively recent geological times. He readily fell into speculations along other lines. With him inductive reasoning took a tectonic rather than a physiographic turn.

Principal among the Duttonian meditations was an estimate of the crustal effects of sedimental loading and unloading through erosion. Reviving astronomer Herschel's well-known view that areas of sedimentation should be regions of insinking of the earth's crust, the endeavour was to show that the converse of this was also true, and that the Utah and Great Basin regions, from which enormous volumes of rock-waste had been so recently removed, should display the evidences of continual and notable upraising. The hypothesis of isostasy was just beginning to take form.

With bent of mind tectonic, Dutton turned eyes to the westward for substantiation of his hypothesis. In the Basin ranges he believed that he had found satisfactory proofs. With Gilbert, Powell, and Russell he fancied that those desert mountains were floating on the earth's soft interior, much after the manner of ice-cakes in a river

at time of the spring break-up. To this quartette the erosional derivation of the Basin ranges seemed entirely out of question. The potency of eolation in arid lands was little suspected.

In the seventies of the last century Dutton was really unable to turn his attention profitably to the Rocky Mountains rearing their peaks to the east of him, in order to test his hypothesis. Geologically the Cordillera was too little known. Its extent was too vast to draw upon in hasty conclusion. It required half a century of uninterrupted investigation by many persons to dislodge the facts that had critical bearing upon fantastic musings. Newer evidences appear conclusive.

The Rocky Mountains seem to be exceptionally well suited to determine the span of isostasy. They occupy a tract which from the earliest geological times has undergone continuous diastrophic oscillation. The area is one which has been repeatedly uplifted. It is one which has suffered again and again extensive planation. The orographic change is never so great as entirely to obliterate the salient features of the different movements. Later upraisings and down-sinkings are especially well marked. The geologic record of events is unusually full.

Since Palæozoic times the Southern Rockies have experienced no less than four distinct and notable upliftings. In the same time they have suffered a like number of total effacements. Each of the ancestral Rockies has appeared no less majestically than the mountains of to-day. Each of the old levellings has been down to the surface of the sea. Peneplanation has been as perfect as is probably ever attained. Great planation periods were during Comanchian, Laramian, Miocene, and Recent times.

Comanchian peneplanation is particularly widespread. It affects the whole continental interior from the Rio Grande to Hudson Bay and from the Sierra Nevada border to the Mississippi River. Even to this day its essential characters are unusually well displayed. Throughout its broad expanse the great Dakotan sandstone conspicuously marks its stratigraphical position and preserves its features. The old plain is one of the smoothest known in all geological history. Only in a few places do there exist any unconsumed residuals standing out as low monadnocks above the general level.

According to the fundamental premise of the isostasy hypothesis, mountains continually rise because of the removal of their summits through erosion, thus lightening the local crustal loads. On the other hand, according to Herschel, areas of sedimentation, or loading, should be tracts of notable crustal insinking. Singularly, the Jurassic ancestral Rockies do not appear to have grown higher as their substance wasted away. They allowed themselves to be worn down to the very level of the sea.

After reaching sea-level, when all their positive volume had vanished, the tract which the Rocky Mountains once occupied,

instead of continuing to rise, or at least remain stationary, proceeds to sink. Indeed, the area may have begun to sink long before it reached base-level. At any rate depression is active until the old plain attains an horizon more than two miles beneath the surface of the ocean. Where once lofty mountains pierced the sky, marine sediments 10,000 feet in thickness accumulate. In spite of the removal of its former great load the net result of the regional vertical movement is notably negative.

Neither does the insinking of the earth's crust in this region appear to have taken place *pari passu* with extensive transference of sediments. Cretacic depression manifestly initiates itself long prior to the beginning of the sedimental loading, perhaps before the mountains were completely demolished. Then, curiously enough, so soon as the enormous loading is finished the region is uplifted again into lofty ranges, as towering, perhaps, as any which appear before or since. Instead of the sequence of events satisfying the isostatic equations, the very reverse proves true all through. Thus is regional unloading succeeded by crustal downsinking, and orogenic upraising is accomplished under maximum load. Surely some orographic force other than the isostatic one is at work.

An especially noteworthy feature concerning the Jurassic revolution in the Southern Rocky Mountain region is that it is not an isolated or unconnected catastrophe. An identical sequence of events is repeated a little later in Laramie time, and again in Miocene time. To-day the same process is going on for a fourth time.

During the epoch when Laramian sedimentation was proceeding around the ancestral Rockies, the latter were themselves razed to the level of the sea. Under a prodigious load of sediments, more than two miles in thickness, the tract is uplifted a distance of between four and five miles; and that before it is appreciably unloaded. Again it is worn down to the ocean level. With the lightening of load on account of erosion there appears to be no recognizable uplifting. After base-levelling, the area instead of rising sinks, until the peneplain is buried under miles of Tertiaries.

In the Miocene period, for a third successive time, are the Rocky Mountains reared to lofty heights, only to be reduced to a low-lying plain. Recently, notable uplifting is repeated. The rejuvenated streams are now about completing their canyon-cutting. On the flanks the winds are levelling and lowering the surface. Soon the mountains will be turned into plain. Are they destined to a new engulfment and a new sinking a mile or two or more beneath the waters of the sea? Experience of the past for three successive times proclaims the affirmative.

In all four orogenic cycles the procedure is the same. Removal of load is not accompanied by further upraising. Rolling of oceanic waters over the tract precedes regional loading. Maximum areal loading is followed by great uplifting. Every stage is met with phenomena diametrically opposed to that which isostasy logically

and vitally demands. The isostatic hypothesis fails utterly to sustain itself before such an array of critical geological testimony.

Turning to the arid Great Basin, from which the chief advocates of the isostatic hypothesis drew their main inspiration, we find that the theory is everywhere rendered nugatory. The hard-rocked mountains do not appear to be growing higher through extensive unloading, but only relatively so because of the fact that erosion peculiar to the desert is going on much faster over the soft intermontane plains. The tectonic structures are mainly not recent but comparatively ancient. The entire surface of the region seems to have been epeirogenically uplifted long prior to the formation of the mountains. In the arid regions the evidences are therefore really against isostasy.

The mountain-tops of to-day probably mark approximately the level of the old uplifted peneplain surface. Genesis of the positive features of desert landscape does not appear to be tectonic but deflative.

The isostatic hypothesis receives strong support from mathematics. Certainly mathematics is a mill which grinds exceeding fine. But, as many thinkers have remarked, what comes out of the mill depends very largely upon what is fed into it. So that, concerning earth problems, there is often little to choose between the rough guess of the geologist and the painstaking calculations of the mathematician.

In view, then, of the recent observations in the Rockies, bearing critically, it seems, upon the theme of isostasy, it appears that the mathematical equations will have to be radically modified in order properly to satisfy the necessary consequences lately derived from the field, or else they will have to be given up as pure fictions.

So far as we are able now to discern, it seems quite manifest that in the hypothesis of isostasy effects are mistaken for causes. At the time, a hundred years ago, when Herschel advanced the idea of crustal insinking, because of sedimental loading, the accepted notion concerning the earth's interior was that it was in a highly plastic condition. Some such conception also pervaded the minds of those who were instrumental in formulating the hypothesis in its later aspects. Since that time, now nearly half a century ago, the phenomena which were so earnestly cited in support are not only readily explained in far simpler ways, but the observations themselves are found to be curiously distorted on account of fancied conditions.

It is not at all strange that the Rocky Cordillera should, on the one hand, so strongly belie the verity of the isostatic hypothesis, and, on the other hand, point so conclusively to the strictly telluric nature of its genesis, and of orogeny in general. Referring characteristic mountain tectonics with which we are acquainted to the secular diminution in rate of the earth's rotation, all the principal orographic features are satisfactorily reproduced in the laboratory.

At best, then, mountain genesis appears to be merely a feeble expression of the larger telluric properties of our globe. As such it is fit subject for most rigid analysis.

The Metamorphism of the Carrock Fell Gabbro; with a Note on the Origin of the Sulphide Veins of the Caldbeck Fells.

By Sidney Melmore, B.Sc., F.G.S.

WITHIN the last two years a cutting has been made at the south-east corner of Carrock Fell, a few yards north of the village of Mosedale, for the purpose of obtaining road-metal. This has opened an interesting section near the margin of the intrusion. The rocks exposed comprise two varieties of gabbro and enclosed Eycott lava. Of the two types of gabbro, that next the lava is of the quartz-bearing variety, exhibiting the prevailing dark-green tint in the hand specimen, and carries large flakes of biotite. This is succeeded by the same type of gabbro, but in a highly metamorphosed condition, at once evident in the hand specimen, which is lighter in colour, primarily owing to the decomposition of the felspars.

Examination of the first gabbro in thin sections under the microscope shows that it also has been metamorphosed, though in a lesser degree than the lighter-coloured variety. The felspars are of the oligoclase-andesine type; the central parts of the crystals are in a saussuritic condition, while the ends are free from decomposition. This condition is particularly noticeable in the larger crystals, and suggests secondary deposition of material differing slightly in chemical composition from the original matter, since the crystals show zonary extinction, and the twin-lamellæ seem to broaden out somewhat at the ends. The extinction angle is greater for the inner than for the outer zones. The crystals themselves are surrounded and cut up by irregular strings of chlorite. Some of the felspars occasionally contain a few minute irregularly shaped colourless plates, depolarizing in colours of a high order, and are doubtless sericite, though they are too small for identification.

The original pyroxene has been converted into pale-green serpentine, which occurs in areas with a more or less sharply defined outline, and having a platy structure. The central parts of these areas are in some cases occupied by small grains of magnetite in a fine-grained mosaic of strongly depolarizing material, and in others by chlorite. Separate fragments of chlorite also occur exhibiting a fibrous structure. Biotite is largely altered to magnetite. This change seems to have progressed from one side of the mica-flake to the other, and can be found in all stages of development.

A specimen picked out of the heap of material already quarried contained a layer of pectolite, about 3·5 cm. in thickness, surrounded by rock identical in every respect to that already described, except

perhaps that the biotite is everywhere completely converted into magnetite.

The pectolite gave on analysis :—

SiO_2	51·94
Al_2O_3 and trace Fe_2O_3	1·56
CaO	14·70
SrO	19·52
MgO	trace
Na_2O	6·08
K_2O	2·26
Combined water	3·40
	99·46
Specific gravity	2·79

Small masses of calcite about 1 cm. across and containing traces of strontium are sometimes found with the pectolite.[1]

A section cut from this pectolite specimen showed under the microscope a thin layer of white mica between the pectolite and surrounding rock, while a narrow string of this mica ran parallel to the main vein of pectolite and at some distance from it. Flakes of sericite can be seen in the felspars adjacent to the vein. Analysis of the rock itself showed only a trace of carbon dioxide, with 0·074 per cent sulphur.

The greater part of the lighter-coloured gabbro, which is about 2 feet in thickness at the margin of the intrusion, consists of plagioclase in a more advanced state of decay; the whole of the crystal is reduced to a translucent mass, through which the core of previously decomposed matter can still be seen in some instances.

Almost colourless serpentine occurs in places, associated with magnetite in large, approximately square sections, and in small granular inclusions, while separate areas of fibrous chlorite are also present.

Occasionally small hook-shaped areas of isotropic material with felspar inclusions can be detected between the felspar crystals. There are also a few well-defined crystals, giving a biaxial interference figure and possessing very weak double reflection, that probably represent a member of the zeolite group. The quartz present in the rock is full of liquid inclusions, the length of the larger of these being about 0·006 mm. and the diameter of the bubble 0·0015 mm.

This rock, which represents a maximum degree of metamorphism observed, loses 2·12 per cent of its weight on ignition. For the normal quartz-gabbro Dr. Harker gives the loss on ignition as 1·50 per cent.[2]

From the above account it may be concluded that hydrothermal metamorphism has taken place at the margin of the gabbro intrusion, resulting in the serpentization of the original pyroxene, accompanied

[1] The material taken for analysis was free from calcite.

[2] Quart. Journ. Geol. Soc., vol. l, 1894, p. 323.

by local sericitization and the formation of pectolite, with extensive alteration of the felspars in the most intense stage.

Evidence of similar changes is to be found in the case of the interfusion rock between the gabbro and granophyre. At the foot of Furthergill Syke there is a variety of this rock in which calcite (without strontium) is uniformly distributed throughout the mass, but otherwise corresponding to that marked "No. 2" in Dr. Harker's section across Furthergill Syke, the specific gravity of which he found to be 2·805.[1] The specific gravity of this altered variety is 2·68. Analysis showed 0·80 per cent of carbon dioxide, corresponding to 1·82 per cent calcite; and 0·023 per cent sulphur.

Amongst the heaps of mine refuse at Roughtengill are to be found specimens of the more basic variety of interfusion rock, containing amygdules and small offshoots of calcite surrounded by a thin layer of pink felspar. This calcite contains traces of strontium.

It has long been supposed that the Carrock Fell complex represents the focus of igneous activity that gave rise to the sulphide veins of the Caldbeck Fells. The structural relationship and other considerations pointing to this conclusion have been demonstrated by Mr. Postlethwaite.[2] Further evidence is also afforded by the way in which the metallic contents of these veins fall off as we recede from this centre, so that at Pottsgill and Ruthwaite the gangue of quartz and barytes makes up practically the whole of the vein contents. It seems reasonable, therefore, to infer that the formation of the sulphide veins is to be correlated with the type of metamorphism already described. It is noteworthy that though the sulphur contents of the normal ultrabasic gabbro from Furthergill Syke is considerably below the average for this type of rock, and that the granophyre at the top of Carrock Fell is also low in sulphur, there is, nevertheless, an increase in the amount of this element at the margin of the intrusion, due either to magmatic segregation or to removal of sulphides from depth by the agents that have brought about the marginal metamorphism. The percentage of sulphur in the rocks under consideration is :—

	Sulphur per cent.
Iron-ore gabbro	0·008
Granophyre	0·014
Interfusion rock	0·023
Serpentinized quartz-gabbro	0·074

From this point of view the sulphide veins are to be regarded as contact veins in the sense of Beyschlag, Vogt, and Krusch's definition, i.e. as "fissures standing open in the contact zone . . . filled with ore deposited from solutions issuing from the magma".[3]

[1] Quart. Journ. Geol. Soc., vol. li, 1895, p. 133.

[2] Trans. Cumb. and West. Assoc. Lit. and Sci., vol. xv, 1889–90, p. 78.

[3] Beyschlag, Vogt, and Krusch, "The Deposits of the Useful Minerals and Rocks": Trans. Truscott, vol. i, 1914, p. 69.

On a Rich Fauna in the *varians* Zone of the Lower Chalk near Reigate.

By Gerard W. Butler, B.A., F.G.S.

THIS fauna resembles that found by Mantell a hundred years ago in the "Chalk Marl" of the South Downs at Hamsey, near Lewes (see specimens in the Natural History Museum, South Kensington), but the occurrence of such a fauna in the familiar North Downs of Surrey seems hitherto unknown. I think, then, that this find should be recorded, that others may, when possible, see how far the faunal richness is local.

The place where my son, R. W. Butler, and I, after living seventeen years in Reigate, stumbled upon this fauna, is on that well-known track, the "Pilgrims' Way"; but it is quite a small excavation, from which a few cartloads of Chalk have been taken for the land. It is about a quarter of a mile west of the "Horseshoe", and where the cart-track from Colley House Farm (south of the railway) meets the "Pilgrims' Way". On the 6 in. Ordnance Survey Map, 1915, Sheet xxvi S.W., it is 3·85 inches from the top edge and 2·35 inches from the right edge. From here a path up the hill runs north-east to some small pits, indicated on this map, where some 50 feet higher than the exposure here described the nodular "Melbourn Rock", the base of the Middle Chalk, is seen. Thus the horizon, though by its fossils clearly in the *A. varians* zone, is above the middle of the Lower Chalk; but in the absence of a continuous section I do not know how much it is above the Upper Greensand.

The fossils found include:—Cephalopoda: *Nautilus*, *Anisoceras armatum* J. de C. Sow., *Turrilites costatus* Lam., *Baculites baculoides* Mantell sp., *Schlœnbachia varians* J. Sow., *Schl. coupei* Brong., *Acanthoceras rotomagense* Brong., *Acanthoceras* sp. (an abnormal specimen, with right and left sides different, intermediate between *A. rotomagense* and *A. mantelli* Sharpe), *Scaphites striatus* Mantell. Lamellibranchiata: *Plicatula*, *Lima* (*Plagiostoma*) *globosa* J. de C. Sow., *Lima* sp., *Limatella*, *Pecten beaveri* Sow., *Inoceramus* (2 or more species), *Cucullæa*, *Cardita*, *Cyprina*, *Tellina*, *Pholadomya decussata* Mantell sp., *Cuspidaria*, *Corbula truncata* Sow., and as more doubtful genera *Pectunculus* and *Nucula*. Gasteropoda: *Pleurotomaria*, *Solariella gemmata* J. de C. Sow., *Solarium*, *Turritella*, *Cerithium*, *Aporrhais* (2 or 3 species), *Avellana cassis* d'Orb. Brachiopoda: *Lingula*, *Rhynchonella mantelliana* Sow., *Rh. martini* Mantell, *Terebratulina striata* Wahl., *Terebratula*, *Kingena lima* Defr. Other fossils: *Discoidea cylindrica* Lam., Echinoid spines, *Serpula*, tooth of *Lamna appendiculata* Agassiz sp., and some black carbonaceous traces of vegetable matter.

In the case of all the Cephalopods, all the Gasteropods except *Solarium*, and all the Lamellibranchs except *Plicatula*, *Lima globosa*, and some of the *Inocerami*, the shell has disappeared, its place being taken by chalk, sometimes ironstained. The chalk,

except in the case of Cephalopod septa, seems always to break so as to show the outside only of these casts, which, if not smudged, are all right for species easily identified by the external form and markings, but are not so good for the small Lamellibranchs.

Some of the best and most interesting specimens were found by my son, while the most interesting of all, the *Lingula*, was found by Miss E. C. Herdman, of Newnham College, Cambridge.

This little *Lingula* is but ·13 in., or 3¼ mm. in length, but by comparison of the pointed end (× 45) with that of the living *L. anatina*, it can, I think, be identified as a dorsal valve. Of course, we know that *Lingula* was living, somewhere, in Chalk times, but its remains seem usually to be found in deposits rich in terrigenous material, such as clays or sands, and so far as I can learn there are only two previous records of *Lingula* from the Chalk of the British Isles, (1) from the very bottom of the Lower Chalk, within 3 feet of the Upper Greensand, from the "Chloritic Marl" at Rye Hill Farm, 3 miles east of Maiden Bradley,[1] and (2) the beautiful small specimen in the Jermyn Street Museum, presented by Clement Reid, from the topmost (*Ostrea lunata*) zone of the Upper Chalk of Britain, from Trimingham.[2]

So anyone finding *Lingula*, however small, in the Chalk should carefully preserve and record it. We may thus perhaps learn something at once about *Lingula* and about the Chalk.

The salient feature of the collection made at this spot is the large number of *Baculites baculoides*. Some pieces of Chalk Marl, weighing as cleaned up only 2 oz., contain nine separate Baculite fragments! Some specimens of the later formed, obliquely ribbed, portion of the shell, show the slight curve that occurs near the aperture of the full grown shell; and other specimens of the earlier, smooth portion break across at the position of the septa.

Mantell[3] says that this Baculite occurs in the South Downs "in every marl pit of the S.E. part of Sussex". In the North Downs it is recorded[4] from this zone in the Medway cut; but otherwise I know of no previous record of it from this zone in the North Downs of Kent or Surrey, and making a special search myself from Betchworth to Reigate inclusive, the only place where I found *Baculites* in the *A. varians* zone is the small lower pit of the "Buckland Limeworks", and there comparatively few and poor specimens. I have, however, found *Baculites baculoides* in the "Melbourn Rock" both at Betchworth Pit and also at one of the small pits north-east of the exposure here described.

I failed to fix the onus of naming my "casts" on someone else, so the blame for the list must rest on me; but I should thank

[1] Jukes-Browne and Scanes, Quart. Journ. Geol. Soc., vol. lvii, 1901, p. 117.

[2] Mem. Geol. Surv., *Cretaceous*, vol. iii, 1904, p. 482. [A small specimen from the *H. subglobosus* zone of Cherry Hinton has been found recently and is now in the Sedgwick Museum, Cambridge.—Ed. Geol. Mag.]

[3] *Fossils of the South Downs* . . . 1822, p. 123.

[4] Mem. Geol. Surv., *Cretaceous*, vol. ii, p. 50.

Mr. R. B. Newton, F.G.S., and Mr. H. A. Allen, F.G.S., for kind sympathy and facilities, and Professor G. A. J. Cole, F.R.S., and Mr. H. Woods, F.R.S., for kindly answering queries as to records of *Lingula* from the Chalk of Ireland and Britain respectively.

The Diatomaceous Earth of Lompoc, Santa Barbara Co., California.

By Sir Nicholas Yermoloff, K.C.B., K.C.V.O., F.L.S.; with a Prefatory Note by Dr. A. Smith Woodward, F.R.S.

LAST year Mr. J. L. Bosqui gave to the Geological Department of the British Museum part of a fossil shoal of herrings found in a marine deposit of diatoms, now being worked for commercial purposes as "celite" in Santa Barbara Co., California. The species represented has since been named *Xyne grex* by Professors Jordan and Gilbert,[1] who exclude it from the genus *Clupea* on account of its thicker enamelled scales, enamelled opercular bones, and strong ventral scutes. The matrix, examined under the microscope, proved to consist so completely of diatoms and other siliceous organisms that it seemed desirable to submit them also to special examination. I was therefore fortunate in enlisting the services of Sir Nicholas Yermoloff, whose extended studies of such organisms make his determination and discussion of these new fossils of particular value. His notes form an interesting supplement to the following short account of the deposit, which was given by Dr. Frank M. Anderson to Professor Jordan (op. cit., p. 14):—

"The white shales about Shorb and El Modena are well known to be diatomaceous, and often considerable bodies of these rocks, that is a considerable thickness of them, is comparatively free from grit. I have been accustomed to regard these shales as of Puente age, as I believe they have been classified by Dr. Arnold, and I have been of the opinion that the Puente formation is middle or lower Miocene in age, and is the equivalent of the Monterey, taken in that sense.

"The Puente group is certainly not the base of the Miocene in the region about Los Angeles, and in the localities mentioned in your letter, namely Shorb and El Modena, the beds are near the middle or a little below the middle of the Miocene section.

"I presume you have some information regarding the large number of fossil fishes found in the diatomaceous beds of near the same horizon some 3 or 4 miles south of Lompoc, Santa Barbara County. The rock here is almost entirely made of diatom material some 600 to 800 feet thick.[2]

[1] D. S. Jordan and J. Z. Gilbert, *Fossil Fishes of Southern California* (Leland Stanford Junior University Publications, University Series, 1919), p. 25, with figures.

[2] The maximum thickness was subsequently stated to be 1,400 feet by Jordan & Gilbert, *Fossil Fishes of the Diatom Beds of Lompoc, California* (loc. cit., 1920, p. 5).

"I believe that the diatoms, or the marine species of the Monterey group, are, or were, northern forms, and lived in the cooler waters of the North Pacific of the Miocene, and were brought south by the ocean currents of the time, and were trapped and impounded in such favourable places as were found along the Pacific coast of the period.

"Such favourable places were local, and more or less land-locked, or protected areas of the sea, free from sedimentation from the land, and where the surface waters of the sea were free to enter and escape, but where they were detained long enough to lose their contents of northern forms under conditions of temperature too high to permit their survival. It appears to me that the deposits of diatomaceous strata, as they are known in California, are all more or less local, and in their occurrence and distribution conform to this idea.

"I have also imagined that the climatic conditions of the coast in middle Miocene times were different from those before and after, for there is a well-known change in the character of the sediments of the Miocene, those of the middle being largely organic, and those of the lower and upper Miocene being generally coarse detrital matter in which the organic contents are inappreciable.

"It may be that physiographic changes in the continental border and in the ocean currents could have brought about these differences in sediments, but there are certain established facts that point to great climatic changes during Miocene times."—A. S. W.

The siliceous remains in the fossil deposit of Lompoc belong to two main and dominating groups of organisms, Dictyochideæ and Diatomaceæ. The deposit contains also a few Radiolaria, some siliceous sponge-spicules, and a few remains of *Lithasteriscus*.

The Dictyochideae are very numerous, in fact nearly as numerous as the Diatoms. This is remarkable and rather peculiar, because, although the genus *Dictyocha* has as a rule a very wide distribution, being present in nearly all fossil Diatomaceous deposits, yet it generally does not appear in other deposits in such dominating numbers as in Lompoc. Thus it is present in the fossil deposits of Richmond, Va., of Simbirsk, Mors, Oran, Oamaru, Sendai, and others; it is also observable in the Baltic (Kiel), and even in the Diatomaceous Oozes of the Antarctic Ocean as collected by H.M.S. *Challenger* at a depth of 1,950 fathoms. *Dictyocha* is, however, absent from the Polycystinous earths of Barbados.

In Lompoc *Dictyocha* is represented by three species, *Dictyocha gracilis* Ehr., *D. speculum* Ehr., and *D. fibula* Ehr. The first two species are abundant, but the third is rather scarce. *D. gracilis* Ehr. is also present in other Californian deposits, for instance, in Los Angeles; but it is much less numerous than in Lompoc.

The number of species of *Dictyocha*, as described by Kutzing, is about thirty-five. Some of the fossil deposits, such as those of

Simbirsk, Mors, and Oran, have species of their own; thus the Russian deposits of Simbirsk contain chiefly *Dictyocha triommata* Kutz.

Dictyocha,[1] a genus established by Ehrenberg, was for a long time thought to be a diatom; later it was included by Haeckel in the Radiolaria, but now it is proved to be a Silicoflagellate. Its species are distinguished mainly by their geometrical outlines and the number of horns, which vary greatly. The species *Dictyocha fibula* and *Dictyocha* (or *Distephanus*) *speculum* are living at the present day; as stated by Sir John Murray, they are met with in the plankton of North European coastal waters.

Besides *Dictyocha*, the Lompoc deposit contains also specimens of *Actiniscus Sirius* Ehr., but they are not dominating like those of *Dictyocha*.

The second main group of siliceous organisms in the Lompoc deposit is that of the diatoms. These are all pelagic and nearly all discoid, with only a very few gonoid forms. The Pseudo-Raphideæ are represented by several species of *Thalassionema*, also by *Raphoneis amphiceros*, var. *Californica*, and by a species of *Tabellaria*, which, however, is scarce. Of the so-called *Pleonemic* diatoms, only one species of *Chatoceros* has been found, namely *C. incurvum* Bail., but the deposit undoubtedly contains many rest-spores of *Chatoceros*, such as *Dicladia*, *Syndendrium*, and *Hercotheca*. The usual absence of *Chatoceros* and *Rhizosolenia* in fossil deposits is a fact which requires explanation, these genera being so common in planktons. Why, while so common and widely distributed, do their remains appear so rarely in the fossil deposits? Several explanations have been suggested. In the first place, *Chatoceros* and *Rhizosolenia* are very delicate organisms, easily destroyed by acids in the preparation of the slides. Secondly, they are neritic forms, thriving rather in coastal waters than in the high seas. Thirdly, it is an undoubted fact, that those diatoms which live in colonies and possess therefore special arrangements to augment their floating surfaces and floating capacities, rarely can fall down after death to the bottom of the ocean otherwise than as separate individuals. This is the reason why colonies of diatoms are, as a rule, so rarely met with in oozes and deposits in general. Indeed, it may be supposed that colonies of diatoms, even after death, continue to float about in the waters as dead plankton. No Raphideæ have been found in the Lompoc deposit, except one species of *Cocconeis*.

All the diatoms in Lompoc are undoubtedly northern forms; indeed, very similar to those usually common in European seas. A few more or less southern species have been observed, but they

[1] An excellent monograph of the genus *Dictyocha* has been published by A. Borgert, "Über die Dictyochiden": Zeitsch. Wiss. Zool., Leipzig, vol. li, 1891.

are so scarce that their presence may perhaps be considered as accidental. Thus there are no *Arachnoidisci*, so common in warmer waters and present even in the Los Angeles deposit; only one *Coscinodiscus patellæformis* Grev. has been found, and no *Craspedodisci* have occurred. Only very few specimens of *Coscinodiscus bulliens* A. S. and *C. turgidus* Rattr., which are truly southern forms, have been observed. There are in Lompoc, it is true, many forms belonging to the group of *Coscinodiscus marginatus* Ehr., but the *marginatus* group can hardly be considered as strictly southern, this group being often met with, as in the Mediterranean Sea. On the other hand, Lompoc has very few representatives of the genus *Stephanopyxis*, or even of *Melosira*, species of which are common in warm waters. The genus *Actinocyclus* is entirely absent; on the other hand, one Actinocycloid form, namely *Euodia gibba* Bail., is not only abundant in Lompoc, but even dominating, just as it is equally frequent in the Moron deposit of Spain. The *Actinoptychus* forms in Lompoc are very poor; there are many specimens of *A. undulatus* Ehr., but they are nearly all of extremely small size, not exceeding some 30 microns. The genus *Asterolampra* is represented by two species, *A. Grevillei* Wallisch. and *A. rotula* Grev., both very frequent, just as they are frequent in the Mediterranean. The genus *Asteromphalus* is also represented by two species, *A. Moronensis* Rattr., common in the Moron deposit, and *A. Hookeri* Ehr., frequent in the Antarctic.

Together with *Dictyocha* and *Euodia*, the genus *Coscinodiscus* dominates in Lompoc. Indeed, these three genera share between them nearly the whole number of organisms in Lompoc.

Of the nine groups of the genus *Coscinodiscus*, as tabulated by Rattray in his "Revision", only five groups are represented in Lompoc. These five groups are the Inordinati, the Excentrici, the Lineati, the Fasciculati, and the Radiati. The four others, the Cestodiscoidales, the Eleganti, the Elaborati, and the Cocconeiformes, are absent.

Of the five groups present, the dominating one is that of the Radiati. This is made evident by the following statement of the respective numbers of species: Inordinati, 1 species; Excentrici, 3 species; Lineati, 8 species; Fasciculati, 13 species; Radiati, 25 species; total, 50 species. Besides these fifty species there are in Lompoc many intermediate transitional forms between the Excentrici and the Lineati, but their occurrence is not remarkable, because such transitional series are also observable in European seas.

A curious fact concerning the Fasciculati group is the following: *Coscinodiscus subtilis* Ehr. so common in European seas, is poorly represented in Lompoc by very few and small specimens; also, no so-called "derivatives" of *C. subtilis*, such as *C. Kutzingii* A. S., *C. Normani* Greg., and *C. Rothii* Grun., are to be found. It would appear as if the *subtilis* group had had no good opportunity

to evolve in Lompoc. On the other hand, another branch of this same group, the *odontodiscus* branch, developed well and safely along two other branch-lines, the *odontophorus* branch and the *interlineatus* branch.

It is remarkable that in the Excentrici group Lompoc possesses the species known under the name of *Coscinodiscus decipiens* Grun., common in the Baltic.

We now turn to the analysis of the dominating Radiati group. Its *radiatus* subgroup, with its derivative *Coscinodiscus Argus* Ehr., is very numerous. The *oculis-iridis* subgroup is also very numerous with its large-sized derivative, *Coscinodiscus borealis* Bail. *Coscinodiscus centralis* Ehr. is also numerous, but, curiously enough, the closely allied *C. concinnus* W. Sm. and *C. nobilis* Grun., common in the Baltic and the Mediterranean, are totally absent.

The *marginatus* subgroup with its numerous derivatives, as shown in the appended list, is fairly numerous, though, as has been stated, this subgroup is already more or less transitional to southern forms. There are two interesting facts to note in its occurrence at Lompoc: in the first place there are many specimens of the so-called *C. robustus*, with exterior "springs" as described on p. 64 of Rattray's "Revision", and peculiar to the Californian Santa Monica deposit. In the second place there are some *Coscinodiscus* forms closely resembling tests of *Pxyidicula*, a genus sometimes considered to belong to the Rhizopods.

These forms have convex valves with punctuate alveoles. The punctæ on the alveoles are very clear and conspicuous. It is just possible that the forms mentioned in the appended list as *C. bipartitus* Rattr., or *C. blandus* A. S. may be tests of *Pyxidicula*, also perhaps *C. robustus* var. *fragilis* Rattr. The specimens from Lompoc classified as *C. bipartitus* are quite similar to the figures given by Professor De Toni in his work, *Analisi microscopica di alcuni saggi di fitoplankton raccolti dalla R.N. Liguria*, but they have no lobes, a circumstance hardly to be considered as unexpected, these lobes being of a non-siliceous composition and therefore not able to withstand the effects of fossilization. On the other hand, some of the forms in question rather resemble *Pyxidicula Mediterranea* Grun., a form not unfrequent in the Mediterranean Sea. The whole question is, however, as yet a subject of controversy requiring further elucidation.

A very curious fact in the Fasciculati group is exhibited in Lompoc in connexion with the species, *C. curvatulus* Ehr., *C. radiolatus* Ehr., *C. radiosus* Grun., *C. aginensis* A. S., and *C. nodulifer* Jan. All these species show something like a distinct nodule, whilst their fasciculate structures are extremely alike, the species passing from one to the other by most insensible gradations.

The genera *Dictyocha*, *Euodia*, *Coscinodiscus*, and *Thalassionema* dominate, and give to the deposit its characteristic facies. It has undoubtedly a much more northern facies than, say, the deposit from Los Angeles, which contains many more southern forms.

The abundance of the *Dictyocha* and *Euodia* is, indeed, the most remarkable feature in the Lompoc deposit.

As to the Radiolaria, the sponge-spicules, and the Lithasterisci, they are not by any means numerous and present no peculiarities. There are also no calcareous remains, such, for instance, as the plates of Holothurians, so well known in the Barbados earth. This is also an important fact, confirming the northern character of the Lompoc deposit.

List of Siliceous Organisms in the Fossil Deposit of Lompoc, Santa Barbara Co., California.

I. DICTYOCHIDEÆ.

Dictyocha.

gracilis Ehr. Abundant and dominating.
speculum Ehr. Abundant.
fibula Ehr. Rare.

Actiniscus.

Sirius Ehr. Frequent.

II. DIATOMACEÆ.

Euodia.

gibba Bail. Abundant and dominating.

Coscinodiscus.

(A) INORDINATI.

turgidus Rattr. Rare.

(B) CESTODISCOIDALES.

None.

(C) ELEGANTI.

None.

(D) ELABORATI.

None.

(E) COCCONEIFORMES.

None.

(F) EXCENTRICI.

excentricus Ehr. Abundant.
decipiens Grun. Frequent.
minor Ehr. Frequent.

Transitional forms to the Group Lineati:

Frequent.

(G) LINEATI.

lineatus Ehr. forma minor. Frequent.
lineatus Ehr. Frequent.
leptopus Grun. Frequent.
anguste-lineatus A. S. Frequent.
marginato-lineatus A. S. Frequent.
bipartitus Rattr. Without lobes. Frequent.
blandus A. S. Frequent.

(H) FASCICULATI.

(*a*) SUBTILIS GROUP.

subtilis Ehr. Rare. Small, poor specimens.
symbolophorus Grun. One specimen in nine slides.
odontophorus Grun. Frequent.
odontodiscus Grun. Frequent.
interlineatus Rattr. Not rare.
extravagans A. S. Not rare.
divisus Grun. Rare.
minutellus Rattr. Rare.

(*b*) CURVATULUS GROUP.

curvatulus Grun. Frequent
nodulifer Jan. Frequent.
œjinensis A. S. Frequent.
radiolatus Ehr. Frequent.
radiosus Ehr. Frequent.

(I) RADIATI.

(*a*) RADIATUS GROUP.

radiatus Ehr. Frequent.
Argus Ehr. Frequent.
obscurus A. S. Rare.

(*b*) OCULUS-IRIDIS GROUP.

oculus-iridis Ehr. Frequent.
borealis Ehr. Frequent.
asteromphalus Ehr. Rather rare.
centralis Ehr. Frequent.
perforatus Ehr. Not rare.
apiculatus Ehr. Not rare.

(*c*) HETEROPORUS GROUP.

heteroporus Ehr. Rare.
crassus Bail. Rare.
gigas Ehr. Frequent.
diorama A. S. Frequent.
bulliens A. S. Rare.
decrescens Grun. Rare.

(*d*) FIMBRIATUS GROUP.

fimbriatus Californica Grun. Frequent.

(*e*) MARGINATUS GROUP.

marginatus Ehr. Frequent.
robustus Grev. Frequent.
robustus bisculptus Rattr. Not rare.
robustus with "springs". Not rare.
See p. 64 Rattray Revision.
robustus fragilis Rattr. Not rare. A *Pyxidicula* (?).

(*f*) OTHER RADIATI.

lunatus Grev.
velatus Ehr. Rare.
subvelatus Grun. Rare.
pectinatus Rattr. Frequent. Transitional.
subaulaco-discoidalis Rattr. Not rare.

ASTEROLAMPRA.

Grevillei Wallisch. Frequent.
rotula Grev. Frequent.

ASTEROMPHALUS.

Moronensis Rattr. Frequent.
Hookeri Ehr. Frequent.

ACTINOPTYCHUS.

undulatus Ehr. Frequent. Very small specimens.

MELOSIRA.

sulcata biseriata.

STEPHANOGONIA (CLADOGRAMMA).

Californica Grun. Not rare.

CHÆTOCEROS.

incurvum Bail. Rare.

REST-SPORES.

Dicladia.
Syndendrium.
Hercotheca mammillaris Ehr.
Other rest-spores.

RAPHONEIS.

amphiceros Californica. Frequent.

THALASSIONEMA.

Nitzschioides Grun. Abundant.
Frauenfeldtii Grun. Abundant.

BIDDULPHIA.

regina Wm. Sm. Rare.
Tuomeyii Bail. Rare.

TABELLARIA.

Sp. (?)

COCCONEIS.

Sp. (?)

REVIEWS.

Von Bau und Leben der Trilobiten. I. Das Schwimmen. II. Der Aufenthalt auf dem Boden. Der Schutz. Die Ernährung. By Rudolf Richter. *Senckenbergiana*, i, pp. 213–38, with 8 text-figures, December, 1919. ii, pp. 23–43, with 13 text-figures, February, 1920.

IN the new periodical *Senckenbergiana*, issued by the Museum of the Senckenberg Naturalists Society in Frankfurt a. M., Rudolf Richter has begun a series of interesting papers on the structure and life of Trilobites. Dr. Richter has been led to this by his studies of Devonian trilobites, and especially of the curious forms found at Gees near Gerolstein and developed with much skill by himself and others at the Senckenberg Museum.

Structurally fitted for a life on the sea-bottom, the trilobites frequently remained on the sea-floor, where they crawled on the ooze or on plants, or rested, either rolled up or outstretched and perhaps hidden by a thin layer of sediment. On the other hand, most, if not all, trilobites could swim by the aid of their many oar-like limbs. The smooth *Phacops–Proëtus* type, with its strong muscular body, was the most agile. The spiny or horned type, represented by *Cyphaspis*, *Acidaspis*, and above all the extraordinary *Lichas armatus* from Gees, was adapted for gentle movement and flotation or balancing in still water. Whether creeping or swimming, when disturbed they rolled up suddenly, and if swimming thus sank rapidly to the bottom. In the rolled-up state the spines, when present, are seen to surround the body.

When swimming the trilobites probably fed on larvæ and other minute organisms. When creeping they probably shovelled up the decaying fragments of plants and animals, being provided in many cases with shovels, ploughshares, or rakes. They did not, however, burrow deeply into the ooze, but kept on or just below the surface.

It will be seen that Dr. Richter's views do not entirely agree with those expressed by Walcott, Dollo, von Staff, and Reck, and others who have speculated on the subject. But they are maintained by ingenious arguments based on material both new and old.

F. A. B.

Doelter's Handbuch der Mineralchemie.

WE have received from the publishers four instalments of this work, which have appeared since 1914. From particulars given on the cover it appears that vol. i, both halves of vol. ii, and the first half of vol. iii are now complete. Of vol. iii there are now to hand parts v–vii. Part v includes a detailed description of a large number of arsenic and antimony minerals, mainly by Dr. H. Leitmeier, of Vienna, and Dr. Henglein, of Karlsruhe; part vi includes the minerals of bismuth and vanadium, and a long

discussion of the chemistry and physics of water, by Dr. R. Kremann, of Graz, with title-page and index of vol. iii, first half; part vii commences the second half of vol. iii with the mineralogy of lithium, sodium, potassium, native copper and copper oxides, rubidium, and silver, also chiefly written by Dr. Leitmeier.

We are glad that it has been found possible to continue publication of this monumental work, which is of the greatest value from the amount of detailed information contained in it, as well as for the numerous references to the literature of modern mineralogy.

Manganese Ores. By A. H. Curtis. Imperial Institute Monographs on Mineral Resources. pp. 118. 1919. Price 3*s*. 6*d*. net.

This is an Imperial Institute publication which reflects credit on the author, who has prepared an interesting and useful monograph, as a result of an exhaustive study of all published information on the subject.

The War focussed attention on manganese ores, as the principal consumers drew their supplies from India, Caucasia, and Brazil, which necessitated ocean transport; and also because efforts to find an efficient substitute for manganese in the manufacture of steel were only partly successful.

Notwithstanding the high selling value of the mineral in recent years, few new deposits have been discovered. In Brazil, where the price incentive was perhaps greater than elsewhere, only one large ore body was found, which even now is not producing. In India no new developments have taken place, but the ferruginous deposits of the Sinai Peninsula, and those of the Gold Coast, both discovered shortly before the War, are now active producers.

The most striking development in the industry since 1914 took place in the United States, which not only intensively operated its own low-grade deposits, but also manufactured practically all its manganese-iron alloys, which in pre-War days had been largely imported from Europe, either in blast furnaces or by electric reduction.

In chapter I the author deals with the occurrence, character, and uses of manganese. It should be mentioned that the large Belgian imports of manganese ore prior to 1914 were principally used in Luxemburg and Germany. Further, the high manganese content of Caucasian mineral refers to the product of washing plants, which constitutes two-thirds of the total output, the "run of mine" being of inferior grade to the Brazilian and Indian ores which are not dressed.

It is interesting to record that the inability of the Caucasus and Brazil to increase their output in pre-War years was almost entirely due to the railways, on which the mineral was carried, being State-owned and operated, although in Russia there has always been the added disability due to labour unrest.

In chapter II useful tables are given regarding British imports and exports of manganese ore and ferro-alloys, and all Empire ore deposits are described, the details regarding the Indian deposits being obtained from the excellent Geological Survey publications. It may be mentioned that the lateritic deposits have proved to be highly ferruginous in depth, although in many cases of good grade at surface—suggesting precipitation of iron prior to manganese.

It is unfortunate that the comparison of costs of production of Brazilian, Russian, and Indian manganese ores is based on figures published many years ago. At the present time the cost of placing the mineral at British ports is probably the lowest for the Gold Coast and Sinai ores, followed by the Caucasian, Indian, and Brazilian supply, but conditions may change at any time, involving alteration in the order given.

Referring to the proposed manufacture of ferro-manganese in India, it may be noted that the alloy was produced at the Tata Works during the War, and in view of the rapid development of the Indian iron and steel industry, it is probable that it will continue to produce its requirements of ferro-alloys.

Mention is made of the utilization of manganese ore for the manufacture of pig-iron containing 2 per cent of manganese, which facilitates the removal of sulphur for basic steel manufacture. The estimated quantity so employed, however, viz. 50 per cent, is high; a more correct figure would be 10 to 20 per cent, which, however, will be greater as the output of basic steel increases.

The South African deposits are not extensive, but may be developed for use in the local steel industry, and the same will probably obtain with both the Canadian and Australian ores.

The Gold Coast manganese ore deposits are important, and as it is probable others will be discovered in the same district, the Colony should become in the future an important source of supply. Successful dressing of the mineral, and the application of mechanical plant for getting and dressing the ore, as well as improvement of the shipping facilities, are necessary to ensure a largely increased export.

In chapter III the ore-bodies in foreign countries are described. It is interesting to note that the successful installation of washing plants in the Caucasus to treat the screenings, amounting to several million tons, accumulated since mining operations commenced, has resulted in a higher-grade product and prolonged the life of the deposit.

No mention is made of the Covadonga deposit in Northern Spain, probably because nothing has been published regarding it in recent years. Manganese and iron-ores occur as boulders, in a clay matrix resting on limestone, as the basement rock. The separation of the ore is effected mechanically, and three qualities of mineral are produced, viz.:—

(*a*) Manganese ore of the highest grade, almost free from phosphorus.

(*b*) Manganiferous iron-ore.
(*c*) Iron-ore.

The quantity of mineral existing is reported to be large, and the output in recent years has been appreciable.

The manganiferous deposits, mostly of low grade, in the United States, the output of which before 1914 was insignificant, produced in 1918, with the help of dressing plants, about half a million tons, containing upwards of 35 per cent manganese. The fall in the selling price of manganese ores, subsequent to the Armistice, caused the closing down of most of the deposits, but owing to the present scarcity of mineral and the high price obtained for it, it is probable that they will be again operated.

In the Lafayette Brazilian deposits at present worked, the alteration from carbonate to oxide continues in depth, but in a number of others originally spessartite the leached portion is shallow. As in India a number of deposits of the lateritic type have been similarly disappointing.

The volume would have been improved by some notes on the manufacture of manganese-iron alloys and a list of the firms engaged in their production.

United States Potash Production.

Potash in 1917. By H. S. Gale and W. B. Hicks. Min. Res. United States, 1917, part ii, pp. 397–481. 1919.

During the year 1917 the shortage of potash due to the War reached its most acute stage, and it is therefore of particular interest to read in this interesting and valuable report the steps that were taken at that time, and the success which was achieved, in meeting the difficulty as it affected the United States. The following table summarizes the production during the year under review :—

Sources of Potash in the United States.	Total Production *Short tons.*	Available Potash, K_2O *Short tons.*
Natural brines	79,876	20,652
Kelp	11,306	3,572
Molasses residues from distilleries	8,589	2,846
Alunite (refined salts and crude and roasted alunite)	7,153	2,402
Dust from cement-mills	13,582	1,621
Wood-ashes	1,035	621
Steffens water from sugar refineries	2,642	369
Wool-washings and other industrial wastes	645	305
Dust from blast furnaces	2,133	185

The report should be in the hands of all who are interested in the potash industry, for it includes not only a very full account of

American resources, actual and potential, but also a useful summary of foreign sources, accounts of the tests for potash, and processes of extraction, and finally a very full bibliography (up to and including 1918) of the whole subject.

ARTHUR HOLMES.

ORIGIN OF THE IRON ORES AT KIRUNA. By R. A. DALY. Vetenskapliga och praktiska Undersökningar i Lappland, Geology of the Kiruna District, part v. pp. 31, with 4 figures. Stockholm, 1915.

THE magnetite ore-bodies of Kirunavaara-Luossavaara are in some respects the finest known examples of the differentiation of oxides from an igneous magma, and there has naturally been a good deal of discussion as to the mechanism by which this has been brought about. Some writers consider the porphyries associated with the ores to be lava-flows, but Daly favours the hypothesis of intrusion. Emphasis is placed on the sequence of rock-types and on the chemical composition of the porphyries as confirmatory of magmatic segregation and particularly of the theory of differentiation in place. The ore-bodies are believed to be basic segregations from the overlying quartz-porphyry intrusion, the upper member of the composite laccolith, accumulated at its base by gravity; while the so-called "inclusions" found scattered throughout its whole thickness are also regarded as units of differentiation, and not xenoliths, as formerly believed. A detailed study of the forms of these masses favours this conclusion. Those masses scattered at higher levels are similar in composition to the ore-bed at the base, and are supposed to have crystallized after the magma had become too viscous to allow them to sink like the earlier ones which formed the ore. An important point is here raised, namely, that since no one disputes that single crystals, say of magnetite, in a magma are formed by differentiation, that is by aggregation of molecules from the solution, there is no reason why compound masses of greater size should not have been formed in an exactly analogous manner, and it is illogical to draw any arbitrary line between such units of varying size by assuming that the larger ones must be xenoliths.

R. H. R.

THE AMISK-ATHAPAPUSKOW LAKE DISTRICT. By E. L. BRUCE. Canada, Department of Mines, Geological Survey Memoir 105. pp. iii + 91, with 7 plates, 4 figures, and a coloured map. Ottawa, 1918.

THIS area lies on the boundary of Manitoba and Saskatchewan, on the divide between three great rivers, the Churchill, Nelson, and Saskatchewan. It forms part of the border of the Canadian shield, about half being occupied by pre-Cambrian rocks and half by Ordovician dolomites. The ancient rocks are divided

into three series, the Amisk series of volcanic rocks at the base, followed by the Kisseynew gneisses; above these are the Lower and Upper Missi series, probably separated by an unconformity, and these are cut by gneissose granite. The main interest is economic, the minerals including gold-quartz veins and chalcopyrite-sphalerite replacements, both believed to be genetically related to the granite batholiths.

On the Origin of the Kuroko of the Kosaka Copper Mine, Northern Japan. By R. Ohashi. Journal of the Akita Mining College, 1920. pp. 11–18, with 2 figures and 2 plates. Akita, 1920.

KUROKO is a dense black ore consisting of sphalerite, galena, and barytes, usually with accessory pyrite, chalcopyrite, and quartz. Its formation has been attributed by most writers to metasomatism, but this explanation presents certain difficulties, especially from the absence of any sign of chemically active substances. The author, therefore, supports the theory of Fukuchi and Tsujimoto, that these deposits are masses of sinter deposited on the floor of the sea by hot springs, contemporaneously with the formation of the clay-beds in which they are now found; the springs were connected with the eruption of the interbedded rhyolites.

REPORTS AND PROCEEDINGS.

The Royal Society.

April 29, 1920.—Sir J. J. Thomson, O.M., President, in the chair.

"The Irish Eskers." By Professor J. W. Gregory, F.R.S.

Eskers are banks of sand and gravel, typically occurring as ridges on the central plain of Ireland, where they were deposited during the recession of the ice at the close of the Glacial period. They have been generally attributed to deposition along glacial rivers, like Swedish *osar*. Their structure and composition indicate that the most important Irish eskers were formed along the margin of the receding ice-sheets by floods of water, due to the melting of the ice.

Irish eskers formed along glacial rivers are relatively small and exceptional. The accumulation of the materials into ridges, and their restriction between about 150 and 300 feet above sea-level, are attributed to the formation of the eskers where the ice entered into a sheet of water, which was probably the sea, since marine fossils are widely distributed in the adjacent drifts, and there are no embankments to maintain glacial lakes at the required level.

It is proposed that the term *esker* should be continued for Irish ridges and mounds of sand and gravel, but that in glacial geology the term *osar* should be used for ridges formed along the glacial rivers, and *kame* used for ridges deposited along the margin of an ice sheet.

GEOLOGISTS' ASSOCIATION.—*May* 7, 1920.

"Implements from Plateau Brick-earth at Ipswich." By Reginald A. Smith, F.S.A.

On the east side of Ipswich, immediately east of Derby Road Station, extensive excavations for brick-earth have brought to light a fine series of flint implements now in Miss Layard's collection at Christchurch Mansion, and described in Journ. R. Anthrop. Inst., xxxiii, 41; xxxiv, 306; xxxvi, 233. With the assistance of the Percy Sladen Trust, a large pit was dug under careful supervision in 1914, and the occurrence of worked flints at different levels verified. There had been 2 feet of contorted gravel above, and a sloping bank of gravel below, a wedge of brick-earth, suggesting the former presence of a river, which can, indeed, be deduced from the levels. Clement Reid recognized Boulder-clay at the bottom of a boring, at 27 feet, and the geology of the site has been studied by Professor Boswell (Proc. Geol. Assoc., xxv, 135), but a comparison with the Caddington Series (*Archeologia*, lxvii, 49) strengthens the argument for plateau deposits late in the palæolithic Drift period, and reopens the question of their relation to the Terrace gravels. The site is on an isolated part of the plateau between the main and lateral valleys of the Gipping and Deben, and is 120 feet above sea-level, the Boulder-clay terminating in an east-and-west line 1 mile to the north.

OPTICAL SOCIETY.—*April* 15, 1920.

"The Rock Crystal of Brazil." By R. R. Walls, M.A., B.Sc.

The author describes the occurrence in the field of the clear variety of quartz known as rock crystal. Although the high plateau of S.E. Brazil is essentially a granite and gneiss country, the rock crystal is not found in the granite itself, but in a series of bedded quartzites overlying the granite. Clear rock crystals occur only in the spaces between the bedding planes, but the planes of the crystals can be traced downwards for several feet across the bedding planes. Huge crystals have thus been formed, and the author illustrated one weighing 13 cwt. Clear crystal and coloured varieties—amethyst, smoky, and cairngorm—were found according to the purity or impurity of the original sandstone.

The sandstone had evidently been "stewed up" and metamorphosed into "crystal", but what was the cause of this is not clear. Intrusive granite suggested itself, but there was no sign of it anywhere. The crystal was found often in the neighbourhood of sericitic schist, which when worked out seemed to occupy a fissure in the horizontally bedded sandstones and quartzites. The sericitic schist contained diamonds, but was very evidently not an alluvial deposit. It appeared, therefore, as if this schist was the highly metamorphosed remains of a volcanic pipe similar to the diamond-bearing pipes of South Africa, and that its intrusion into the sandstones and quartzites had metamorphosed the latter into "crystal".

LIVERPOOL GEOLOGICAL SOCIETY.

April 13, 1920.—Mr. W. T. Walker, B.Sc., F.G.S., President, in the chair.

The following papers were read :—

1. "The Bellevale Borehole." By F. T. Maidwell, F.G.S.

The boring was made in 1919 by the Widnes Corporation for water at Bellevale, Little Woolton, close to the Liverpool city boundary, and reached a depth of 704 feet below the surface. Full details were given of the strata penetrated, which were almost entirely of Middle and Lower Bunter Sandstones.

2. "Coastal Changes at the Mouth of the Alt." By C. B. Travis.

The encroachments of the sea on the Cheshire and Lancashire coasts of the Mersey have attracted considerable attention during the past few months, and particularly on the northern shore of the estuary, where the spectacular feature of the menace of destruction of a number of fine detached residences at Hall Road has created much popular interest. The erosion which has taken place in the latter locality has been the subject of continuous detailed observations by Mr. Travis, who has carried out a series of surveys during the last twelve months dealing with the position of the River Alt on the foreshore, and of the changes of the high water-mark of the tides at various periods since 1893. Contrary to general supposition, the advance southward of the River Alt is no new feature, but brings part of the series of oscillations to which this river between Hightown and Waterloo has been subject over a very long period. By reproductions of old maps and charts, and recent surveys, the striking changes in the position of the outlet channels of the river during the last three centuries were illustrated, and it was shown that no periodicity can as yet be definitely established in relation to these fluctuations.

Details of the recent erosive effects and calculations of the loss of land suffered along this part of the South Lancashire coast, particularly during the past seven years, were given. The accretion of blown sand which has taken place along other parts of the same coast contemporaneously with the erosion was referred to, and the noteworthy gain of land by natural and artificial means in the neighbourhood of what is now the Altcar Rifle Range, and the formation and development of the salient of accretion known as Formby Point, since the seventeenth century, were described.

CORRESPONDENCE.

GAULT AND LOWER GREENSAND NEAR LEIGHTON BUZZARD.

SIR,—Although it would be easy to reply in detail to Mr. Lamplugh's letter on this subject, published in your issue of last month, we have no desire to do so. We are satisfied that a careful

perusal of our recent paper provides the most convincing reply; and since our method of attacking the problem differs so widely from that adopted by Mr. Lamplugh, we feel that a controversy would be fruitless.

F. L. Kitchin.
J. Pringle.

London.
May 12, 1920.

Sir,—Although the subject of the Bournemouth Chines is chiefly of local interest, as Mr. Bury in his paper in the February number has referred several times to my views, may I be permitted a few words in reply?

Mr. Bury's paper chiefly deals with the seaward aspect of the chines, and curiously he omits mention of the one determining feature which is common to all the chines, and more than anything else is responsible for their form, depth, contour of sides, and angle of recession in cliff-face. This is the position, thickness, and number of the clay-beds which occur in the friable sandy strata from which the chines have been carved by the action of land water. In thirty years residence in the town I have more and more been struck by this, and led to attribute less and less to sea action at the cliff-face.

If any visitor will examine the shorter and lesser chines, such as Honeycombe Chine, east of Boscombe pier — which is not mentioned by Mr. Bury—also Middle Chine, Little Durley Chine, and Canford Cliff Chine, they will readily admit the influence of this factor. That the larger chines—Branksome, Bourne Valley, and the mouth of the Bourne, and probably Boscombe Chine—are remains of the old Solent River drainage system cannot be doubted. But all have been deepened and widened since the sea invaded Bournemouth Bay, by the action of land streams causing constant washing out of sand and slipping of clay-beds as they were uncovered.

I have never thought it necessary to invite the aid of glaciation or a hypothetical coombe-rock to account for what is otherwise easily explained. At the close of the Glacial period and the beginning of Neolithic times, floods from the melting of ice-sheets further north first eroded the surface and then deposited the sheet of plateau gravel which we find covering the strata around Bournemouth to-day. This occurred when the Bourne Valley was half its present depth. The plateau gravel is found in places down what Mr. Bury considers the old valley level in Branksome and Alum Chines. The present chine level has been formed since the close of the Glacial period. The Solent River system had been destroyed long before this, almost immediately on the sea breaking through the range of chalk hills which soundings show must have occurred not far east of Ballard Down, the period being either during or just before the raised beaches were formed.

With regard to the angle of the cliff-slope, my observations entirely confirm Mr. Carus Wilson's opinion that the cliffs are steeper now than formerly.

W. T. Ord, F.G.S.

Bramber,
18 Littledown Road,
Bournemouth, E.

NOMENCLATURE OF THE HEAVY LIQUIDS.

Sir,—In dealing with laboratory methods for the separation of minerals of different densities, some writers speak of Klein's solution, Brauns' solution, Rohrbach's solution, and Sonstadt's (or Thoulet's) solution. Others use the chemical names of the fluids—cadmium borotungstate, methylene iodide, etc. This double nomenclature is confusing and a tax on the memory, and it would be well if one or other set of names were adhered to and the other abandoned.

In the case of the double iodide solutions, the personal name has the advantage of brevity over the chemical. The desire to give honour where honour is due may also incline some workers to its use. But in this respect we are far from consistent. Bromoform, the most generally useful of all the heavy liquids, might with justice be called Schroeder van der Kolk's liquid. Moreover, Professor Brauns was not the discoverer of methylene iodide, he was merely the first to describe its application to mineralogy; and some of the other authors have even slighter claims to the liquids with which their names are associated.

The chief objection to the personal name is that it has no intrinsic relation to the fluid and suggests none of its properties. The chemical name, on the other hand, specifies the composition of the fluid referred to, and so recalls to mind its physical properties. The chemists will not be persuaded to call methylene iodide Brauns' solution, though they are not free from a similar practice (e.g. Fehling's solution, Condy's fluid, etc.). It would be a good thing if mineralogists would avoid the needless duplication of names and always use the chemical instead of the personal names for the heavy liquids.

G. M. Davies.

17 Elmwood Road, Croydon.
May 4, 1920.

OBITUARY.

Walter R. Billings.

Through the death of Mr. Walter R. Billings, Canada has lost a citizen of unusual attainments. His death occurred at his home in Ottawa on March 1, in his 71st year. Mr. Billings was an architect by profession and a palæontologist by natural taste and inclination.

perusal of our recent paper provides the most convincing reply; and since our method of attacking the problem differs so widely from that adopted by Mr. Lamplugh, we feel that a controversy would be fruitless.

F. L. Kitchin.
J. Pringle.

London.
May 12, 1920.

Sir,—Although the subject of the Bournemouth Chines is chiefly of local interest, as Mr. Bury in his paper in the February number has referred several times to my views, may I be permitted a few words in reply?

Mr. Bury's paper chiefly deals with the seaward aspect of the chines, and curiously he omits mention of the one determining feature which is common to all the chines, and more than anything else is responsible for their form, depth, contour of sides, and angle of recession in cliff-face. This is the position, thickness, and number of the clay-beds which occur in the friable sandy strata from which the chines have been carved by the action of land water. In thirty years residence in the town I have more and more been struck by this, and led to attribute less and less to sea action at the cliff-face.

If any visitor will examine the shorter and lesser chines, such as Honeycombe Chine, east of Boscombe pier — which is not mentioned by Mr. Bury—also Middle Chine, Little Durley Chine, and Canford Cliff Chine, they will readily admit the influence of this factor. That the larger chines—Branksome, Bourne Valley, and the mouth of the Bourne, and probably Boscombe Chine—are remains of the old Solent River drainage system cannot be doubted. But all have been deepened and widened since the sea invaded Bournemouth Bay, by the action of land streams causing constant washing out of sand and slipping of clay-beds as they were uncovered.

I have never thought it necessary to invite the aid of glaciation or a hypothetical coombe-rock to account for what is otherwise easily explained. At the close of the Glacial period and the beginning of Neolithic times, floods from the melting of ice-sheets further north first eroded the surface and then deposited the sheet of plateau gravel which we find covering the strata around Bournemouth to-day. This occurred when the Bourne Valley was half its present depth. The plateau gravel is found in places down what Mr. Bury considers the old valley level in Branksome and Alum Chines. The present chine level has been formed since the close of the Glacial period. The Solent River system had been destroyed long before this, almost immediately on the sea breaking through the range of chalk hills which soundings show must have occurred not far east of Ballard Down, the period being either during or just before the raised beaches were formed.

With regard to the angle of the cliff-slope, my observations entirely confirm Mr. Carus Wilson's opinion that the cliffs are steeper now than formerly.

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NOMENCLATURE OF THE HEAVY LIQUIDS.

Sir,—In dealing with laboratory methods for the separation of minerals of different densities, some writers speak of Klein's solution, Brauns' solution, Rohrbach's solution, and Sonstadt's (or Thoulet's) solution. Others use the chemical names of the fluids—cadmium borotungstate, methylene iodide, etc. This double nomenclature is confusing and a tax on the memory, and it would be well if one or other set of names were adhered to and the other abandoned.

In the case of the double iodide solutions, the personal name has the advantage of brevity over the chemical. The desire to give honour where honour is due may also incline some workers to its use. But in this respect we are far from consistent. Bromoform, the most generally useful of all the heavy liquids, might with justice be called Schroeder van der Kolk's liquid. Moreover, Professor Brauns was not the discoverer of methylene iodide, he was merely the first to describe its application to mineralogy; and some of the other authors have even slighter claims to the liquids with which their names are associated.

The chief objection to the personal name is that it has no intrinsic relation to the fluid and suggests none of its properties. The chemical name, on the other hand, specifies the composition of the fluid referred to, and so recalls to mind its physical properties. The chemists will not be persuaded to call methylene iodide Brauns' solution, though they are not free from a similar practice (e.g. Fehling's solution, Condy's fluid, etc.). It would be a good thing if mineralogists would avoid the needless duplication of names and always use the chemical instead of the personal names for the heavy liquids.

G. M. Davies.

17 Elmwood Road, Croydon.
May 4, 1920.

OBITUARY.

Walter R. Billings.

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